PETROBRAS

EFFECTS OF E27.5 AND E30 ON VEHICLES, MOTORCYCLES AND GASOLINE ENGINES

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Technical Report

SUPPLY R&D

Performance of Products in Engines

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Leopoldo A. MIguez de Mello

CENTRO DE PESQUISAS E DESENVOLVIMENTO LEOPOLDO A. MIGUEZ DE MELLO
[RESEARCH AND DEVELOPMENT CENTER LEOPOLDO A. MIGUEZ DE MELLO]
SUPPLY R & D Product Performance in Engines

EFFECTS OF E27.5 AND E30 ON GASOLINE-POWERED VEHICLES

RT DPM 008/14

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SUMMARY

At the request of the Ministry of Mines and Energy, PETROBRAS carried out a technical study to assess the impact of an increase in the percentage of anhydrous ethyl alcohol fuel (AEAF) in the automotive gasoline marketed in the country, specifically for the contents of 27.5 and 30%, in engines and vehicles powered exclusively by gasoline.

Emission and fuel-economy tests were carried out at LEV [Laboratório de Ensaios Veiculares = Laboratory of Vehicle Tests] at CENPES and at Instituto LACTEC, in addition to performance tests [(cold starting, cold engine drivability and re-acceleration ("speed recovery")] at the test track of CAEx [Centro de Avaliação do Exército = Army Testing Center]. For these tests, gasoline-powered vehicles in good working order were used, with different fuel injection technologies and representative of the L2 to L6 phases of the Programa de Controle da Poluição do Ar por Veículos Automotores (PROCONVE) [Motor Vehicle Air Pollution Control Program].

Engine test evaluations were also carried out at CENPES's Engine Testing Laboratory [LEM], by checking the typical performance curves at 100% and 50% load, in order to evaluate the effect of the ethanol content. The exhaust emissions temperature was also assessed. There was concern with regard to the possible effects of a temperature increase in engines with direct injection technology.

In relation to fuels, in the emission and fuel-economy tests, ethanol contents of 22, 25, 27.5 and 30% v/v added to the gasoline A emissions standard were evaluated. These fuels were called E22, E25, E27.5 and E30, and the gasolines E22 and E25 were established as references for these tests. For the other tests (road and engine performance in the dynamometer), the same levels of 27.5 and 30% were added to an S50 production gasoline and compared to the same gasoline with EAC 25% v/v, used as reference.

In addition to the physical-chemical analyses contained in the specification, tests of volatility, lubricity and oxidative stability were carried out in order to observe whether the increase in the content of ethanol has a significant effect on these variables.

In the following conclusions, emphasis is given to the evaluation of the results obtained with the E27.5, as compared to the E25 currently available in the market, based on the sample of vehicles and motorcycles used.

In the emissions tests carried out in 8 vehicles, it was observed that, with the increase of the ethanol between the levels of 22 and 30% v/v, there was a maintenance or reduction of hydrocarbon (THC and NMHC), CO and CO2 emissions. The NOx emission of vehicles L3 and previous ones also followed this trend, except that for L4 vehicles and beyond, there was a trend towards an increase. For aldehydes there was also a trend towards an increase. It should be noted that in vehicles where there was an increase in NOx and/or aldehydes, the emission levels were still below the PROCONVE limit. With respect to fuel economy (urban and on the highway), a reduction trend was identified in all vehicles.

In the direct comparison of the E27.5 and E25 results, statistically significant changes were observed nly for CO (a reduction of up to 11% in the two L2 vehicles), and for fuel economy (reduction of 1% in one of the two L3 vehicles and in the sole representative of phase L4). In the other four vehicles tested, which were one L3, two L5 and one L6, the emissions of CO, THC, NMHC, NOx and CO2, as well as the fuel economy, did not present statistically significant differences.

In relation to the maneuverability and cold start tests performed at 0°C, the two L2 vehicles tested showed faults that could not be attributed to the increase in ethanol content of the fuel, since they occurred with both E25 and E27.5 and E30. With regard to the six vehicles in the L3, L4, L5 and L6 PROCONVE phases, no failures were observed in any of the stages of the cold start and drivability tests, all of which were completed normally.

There were no significant variations in vehicle performance in the speed recovery tests.

For the five motorcycles tested in the same way as the automobiles, a general trend of reduction in THC and CO emissions was observed, and this accompanied the increase in ethanol content between the levels of 22% v/v and 30% v/v. For CO2 emissions and for fuel economy, there was no definite trend. In NOx emission, however, a trend towards the maintenance or increase was observed. In the case where the pollutant elevation was verified, the highest value found was below the respective PROMOT limit.

In the comparison between the results obtained with E27.5 and E25, there were reductions of up to 7% in THC, 18% in CO and 1% in fuel economy, in addition to an increase in NOx (13%) and CO2 (3%).

Regarding the drivability, cold start and speed recovery tests carried out by ABRACICLO, it considered the use of E27.5 viable.

Considering the tests on motor test stands, the results of actual power at full load did not have statistically significant performance differences, except under conditions of up to 2500 rpm, with reductions of 0.8% to 2.3%. Specific consumption, both at full load and at partial load, increased by up to 2.5%. With respect to the exhaust temperature, which is more critical at full load, these differences oscillated up to 1% around the values obtained for E25, which is within the experiment's measurement uncertainty.

As for the physicochemical properties evaluated, it was observed that all results were within the uncertainty of the experimental methods used. Therefore, the increase in the anhydrous ethanol content in gasoline from 25 to 27.5% has little influence on vapor pressure, lubricity and stability to oxidation of gasoline C.

As agreed at the meetings conducted by MME, the possible effects of the new ethanol contents on component durability were not part of the scope of this work. This assessment should be carried out by the automobile industry and by the segment for two-wheeled motor vehicles, represented, respectively, by ANFAVEA and ABRACICLO.

1. INTRODUCTION

According to national legislation, the ethanol content of Brazilian gasoline varies within the range of 18 to 25% v/v of anhydrous ethanol fuel. Currently the 25% v/v content is in force.

In the current scenario, where there is a strong demand for Otto cycle fuels and a growth in imports of gasoline to supply the domestic market, the Ministry of Mines and Energy (MME) requested a study from PETROBRAS on the possible effects of higher ethanol levels in the blend with gasoline, with regard to performance of gasoline-powered vehicle engines, since these variations would not impact flex-fuel vehicles.

The demand was sent to CENPES and a work plan was developed and later approved by the GT made up of ANFAVEA, ABRACICLO, ABEIFA, UNICA, INMETRO, INT, LACTEC, PETROBRAS, MAPA, MDIC and MME, under the management of MME.

This plan included the evaluation of the gasoline-ethanol blends with 22, 25, 27.5 and 30% v/v EAC in terms of emissions, fuel economy and performance (cold start, drivability and recovery speed) in vehicles and motorcycles, test bench engine performance, and analytical tests of lubricity and gum of the blends.

Eight gasoline-powered vehicles with different fuel injection technologies were selected, and all were approved according to phases L2 to L6 of the Programade Controle da Poluição do Ar por Veículos Automotores [Control of Air Pollution by Motor Vehicles Program] - PROCONVE. According to data collected from the Inventário Nacional de Emissoes Atmosféricas (1) [National Air Emissions Inventory], in 2012 the fleet of light vehicles consisted of 36% of gasoline-powered vehicles and 64% of flex-fuel vehicles, and ethanol. Of the share of gasoline-powered vehicles, the technologies that together represented around 94% of this fleet were selected.

Following the same line of reasoning, five gasoline motorcycles were selected, with different technologies that met the Pre-M1, M1, M2 and M3 phases of the Programa de Controle da Poluição do Ar por Motociclos e Veículos Similares [Program for Control of Air Pollution by Motorcycles and Similar Vehicles] - PROMOT. According to data from the same National Inventory, in 2012 these motorcycles represented 100% of the gasoline fleet. It should be noted that this fleet represented 84% of the national fleet of this segment, while the remaining 16% were flex-fuel motorcycles.

For the work plan, a 13-week period beginning on July 7 was established, as per the schedule presented in table I below:

Table I - Program of tests of ethanol percentage in gasoline

PHASES	ACTIONS	WEEK												
		07/7	14/7	21/7	28/7	04/8	11/8	18/8	25/8	01/9	08/9	15/9	22/9	29/9
INITIAL	Approving the Work Plan													
TESTS (CENPES)	Obtaining and Preparing the Gasoline C (22, 25, 27.5 and 30%)													
	Physicochemical characteristics / Lubricity / gum acceleration													
	Obtaining the vehicles for testing													
	Vehicle Emissions and Consumption Tests													
	Motorcycle Emissions and Consumption Tests													
	Road Performance Tests (vehicles only)													
	Engine tests on test bench													
	Drivability Tests (cold and hot start) (only vehicles)													
	Evaluation of results / MME Presentation													
	Return of leased vehicles													
	Issuance of RT													

Performance tests on motorcycles were performed by professionals chosen by ABRACICLO on the CAEx test track, and the results and conclusions were incorporated into this report.

2. FUELS USED

For the emissions and fuel-economy tests, four test gasolines were formulated, as follows:

- Gasoline **E22**: formulated with 78% v/v standard A gasoline and 22% v/v EAC;
- Gasoline **E25**: formulated with 75% v/v standard A gasoline and 25% v/v EAC;
- Gasoline **E27.5**: formulated with 72.5% v/v standard A gasoline and 27.5% v/v EAC;
- Gasoline **E30**: formulated with 70% v/v standard A gasoline and 30% v/v EAC.

The specifications of the standard A gasoline and EAC for carrying out pollutant emission and fuel-economy tests are defined, respectively, by ANP resolutions number 5 (2) and number 6 (3) of February 24, 2005.

For the road performance tests, test bench characteristic curves and volatility, lubricity and oxidation stability analyses, three other test gasolines were formulated from the same gasoline sample A as below:

- Gasoline **E25**: formulated with 75% v/v commercial A gasoline and 25% v/v EAC;
- Gasoline **E27.5**: formulated with 72.5% v/v commercial A gasoline and 27.5% v/v EAC;
- Gasoline **E30**: formulated with 70% v/v commercial A gasoline and 30% v/v EAC.

The physicochemical analyses of the fuels used are in Annex II of this report.

3. VEHICLES AND MOTORCYCLES USED

In the selection of vehicles and motorcycles, the following were sought: representativeness of manufacturers, mileage compatible with the age of the vehicle, cylinder capacity and fuel injection technologies in relation to the circulating fleet of gasoline-powered vehicles. According to data from the latest National Inventory (1), in 2012 36% of the passenger cars fleet used exclusively gasoline, while for the motorcycle fleet this percentage was 84%. Considering this composition, the vehicles selected for the present work represent about 94% of the fleet of gasoline-powered vehicles, while the motorcycles cover 100%.

Regarding the state of operation, vehicles chosen were in good condition, meaning those that did not have drivability problems and did not exceed the emissions of the vehicle inspection and maintenance program limits, established in CONAMA Resolution 418/2009, regardless of whether they meet the respective PROCONVE approval limits. Therefore, no special maintenance was carried out on the vehicles before the tests. The intention was that the sample tested would reflect more realistically the condition of the national fleet. Tables II and III indicate the main characteristics of vehicles and motorcycles selected for the job:

Table II - Main characteristics of vehicles

Code of VEHICLE	*Phase*	*Year / Model*	*Km driven*	*Engine capacity*	*Transmission*	Catalytic converter	Injection System
L2A	L2	1995/1996	251030	1.0	manual	Yes	electronic carburetor
L2B	L2	1995	> 141867	1.6	manual	Yes	single-point injection
L3A	L3	2001	155392	1.8	automatic	Yes	multipoint injection
L3B	L3	1999/2000	229332	1.0	manual	Yes	multipoint injection
L4A	L4	2008	98349	2.0	automatic	Yes	multipoint injection
L5A	L5	2009/2010	72471	1.6	manual	Yes	multipoint injection
L5B	L5	2010	40547	2.0	automatic	Yes	multipoint injection
L6A	L6	2013/2014	6035	1.6	automatic	Yes	turbocharged direct injection
L6B	L6	2013/2014	5333	1.6	automatic	Yes	turbocharged direct injection

Table III - Main characteristics of motorcycles

Motorcycle Code	PROMOT Phase	Year	Km traveled	Engine capacity	Catalytic converter	Injection System
PM1 A	PM1	2002	91719	125	No	carburetor
M1 A	M1	2005	59374	150	No	carburetor
M2 A	M2	2008	50307	125	No	carburetor
M3 A	M3	2009	124	125	Yes	electronic injection
M3 B	M3	2010	105	300	Yes	electronic injection

4. EMISSION AND FUEL-ECONOMY TESTS

4.1. VEHICLES

4.1.1. Test Methodology

In the 'light vehicles' test, the emission of pollutants and fuel economy are measured on a chassis dynamometer (fig.1). This equipment is set to provide the drive wheels of the vehicle with a resistance equivalent to the friction, inertia and aerodynamic forces to which it would be subject under normal conditions of use.

Figure 1 - Vehicle during exhaust emissions tests at Cenpes.

The driver drives the vehicle according to a driving cycle with starts, accelerations, decelerations and stops, while an aliquot quantity of the emissions is collected in containers (sample balloons). It should be noted that the Brazilian standard urban driving cycle replicates the North American FTP-75 cycle. It simulates the driving of a vehicle along a mixed route of highways and urban roads, with a duration of approximately 45 minutes, at an average speed of 31.5 km/h and a maximum speed of 91.2 km/h. In addition to the urban cycle, a driving cycle is also carried out in typical road situations, but, in this case, only for calculating the fuel economy. Figure 2 shows a graph in which the vehicle speeds are indicated in each step of the FTP-75 cycle.

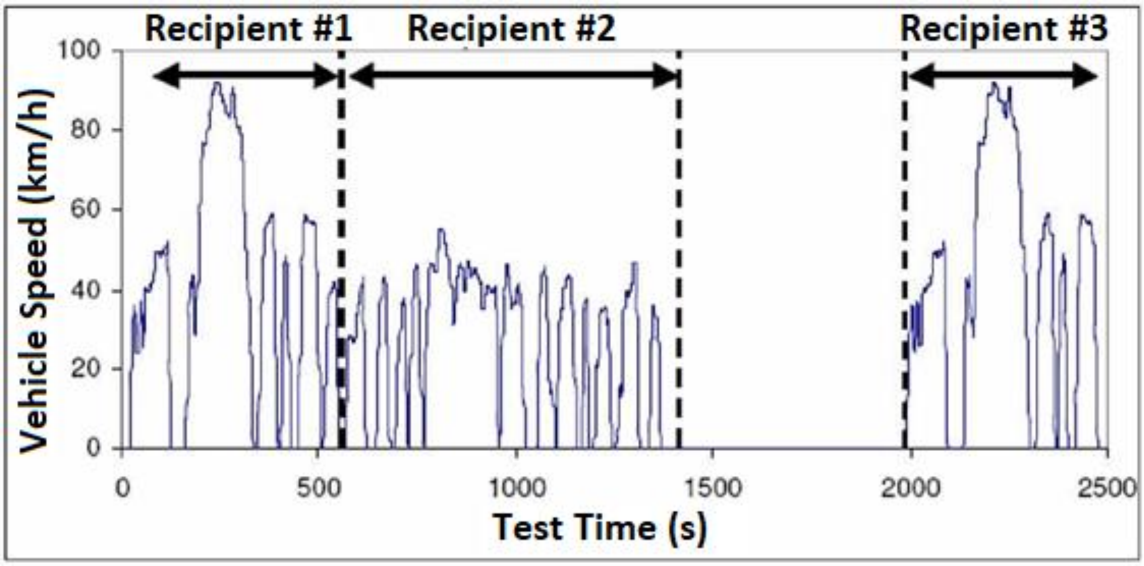

Figure 2 - Driving cycle for emission test according to ABNT NBR 6601.

After the test, the gas stored in the sample flasks is sent to line analyzers, which quantify total hydrocarbons (THC), carbon monoxide (CO), carbon dioxide (CO2), nitrogen oxides (NOx), and methane (CH4). The hydrocarbons are measured with a hydrogen flame ionization detector (FID). The emission of methane is determined by a flame ionization detector (FID), after the gas sample passes through a chromatographic column that separates the methane. The emission of non-methane (NMHC) gases is determined by calculating the difference between the total hydrocarbons (THC) measurements and the methane measurement. A chemical luminescence detector is used in the determination of nitrogen oxides (NOx). Non-dispersive infrared (NDIR) analyzers determine CO and CO2. The fuel economy of the vehicle in the urban and road cycles is determined by measuring the carbon of the exhaust gases containing this element (THC, CO and CO2).

Samples for the determination of aldehydes (formaldehyde + acetaldehyde) in Otto cycle vehicles are collected during the test by bubbling the exhaust gas diluted in impingers containing an adsorber solution. The aldehydes are subsequently analyzed by high performance liquid chromatography (HPLC).

The Brazilian standards governing the urban driving cycle and the quantification of its pollutants are NBR 6601 (4) and NBR 12026 (5). For the measurement of fuel economy in the urban and road cycle, standard NBR 7024([6]) is used.

To allow increased statistical significance of the data, at least three tests were performed in each vehicle with each one of the test fuels.

4.1.2. Methodology for Statistical Analysis

As a first step, the F test of the Analysis of Variance (ANOVA) was carried out separately for each pollutant and vehicle, in order to verify the cases in which the fuel had influence on the result, considering a level of significance of 95% ($p = 0.05$). In cases where this occurred, a Regression Analysis was performed for a linear fit. The level of significance for this analysis was also $p <0.05$.

In the Regression Analysis, the data are statistically treated to verify the existence of a functional relationship between a dependent variable and one or more independent variables. With the resulting equation, we try to better understand the phenomenon that relates the variables, to observe behavior trends and estimate results (). The graphs resulting from the Regression Analysis that was performed are listed in Annex III.

Once the models were established, they were used to estimate pollutant emissions and fuel economy for the levels tested, using this value to compare the results of the different fuels. In these comparisons, the error associated with the surveyed model was taken into account, so that when the difference between the results was lower than its confidence interval, it was considered that it was not possible to assert that there is a statistically significant difference ("no diff.").

4.1.3. Results and Discussion

All vehicles tested in which the odometer reading was less than 80,000 km driven (L5 and L6 vehicles) met the emission limits prescribed by PROCONVE for this mileage.

Figures 3 to 9 show the mean values of the results obtained in the exhaust emission and fuel-economy tests, as well as the regression line, only in cases where the Variance Analysis indicated that there was significant influence of the fuel. They also indicate the limits of PROCONVE for 80,000 km.

Annex III shows graphs of the experimental points, regression lines and curves of the error inherent in the fit. In the same Annex, there is a table with the values of the regression coefficients, as well as the estimated values for points E22, E25, E27.5 and their respective confidence intervals.

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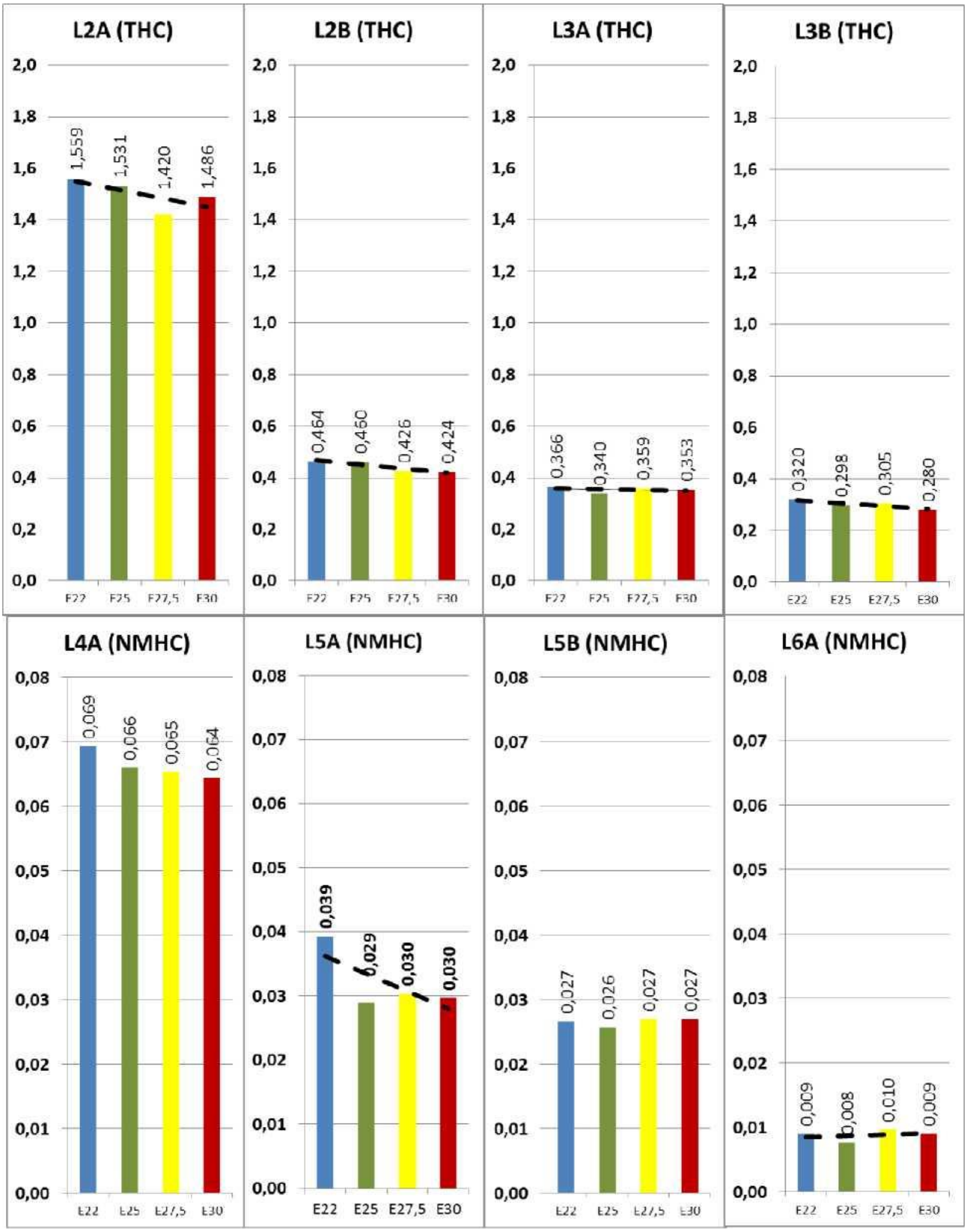
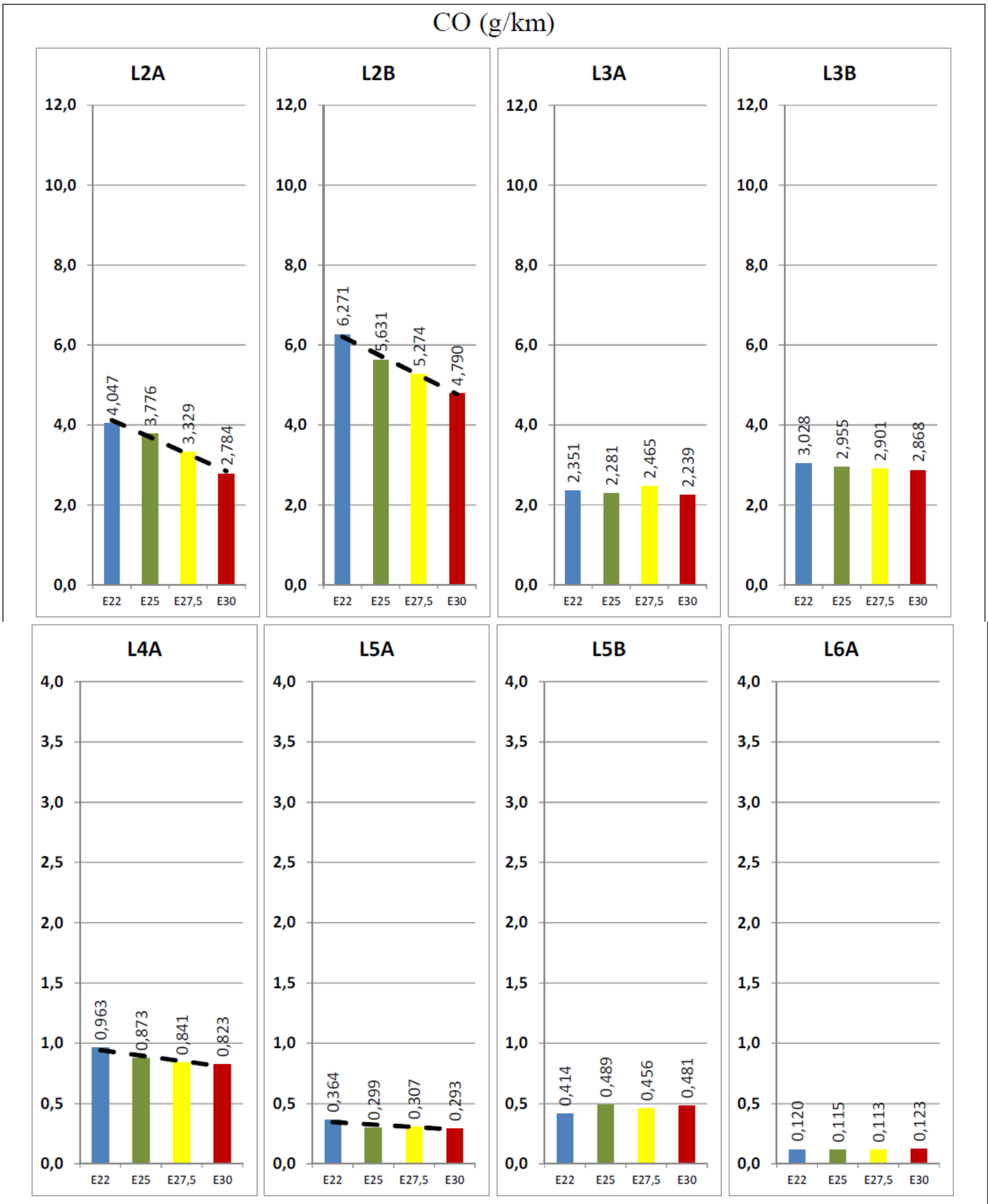
THC (L2, L3) and NMHC (L4, L5 and L6) in g/km



Notes: (1) PROCONVE limits for 80,000 km (g/km): L2 = 1.20, L3 = 0.3, L4 = 0.16, L5 = 0.05, L6 = 0.05.

(2) The regression models of the L4A and L5B vehicles were not presented because ANOVA did not indicate that the influence of the fuel is significant at a level $p < 0.05$.

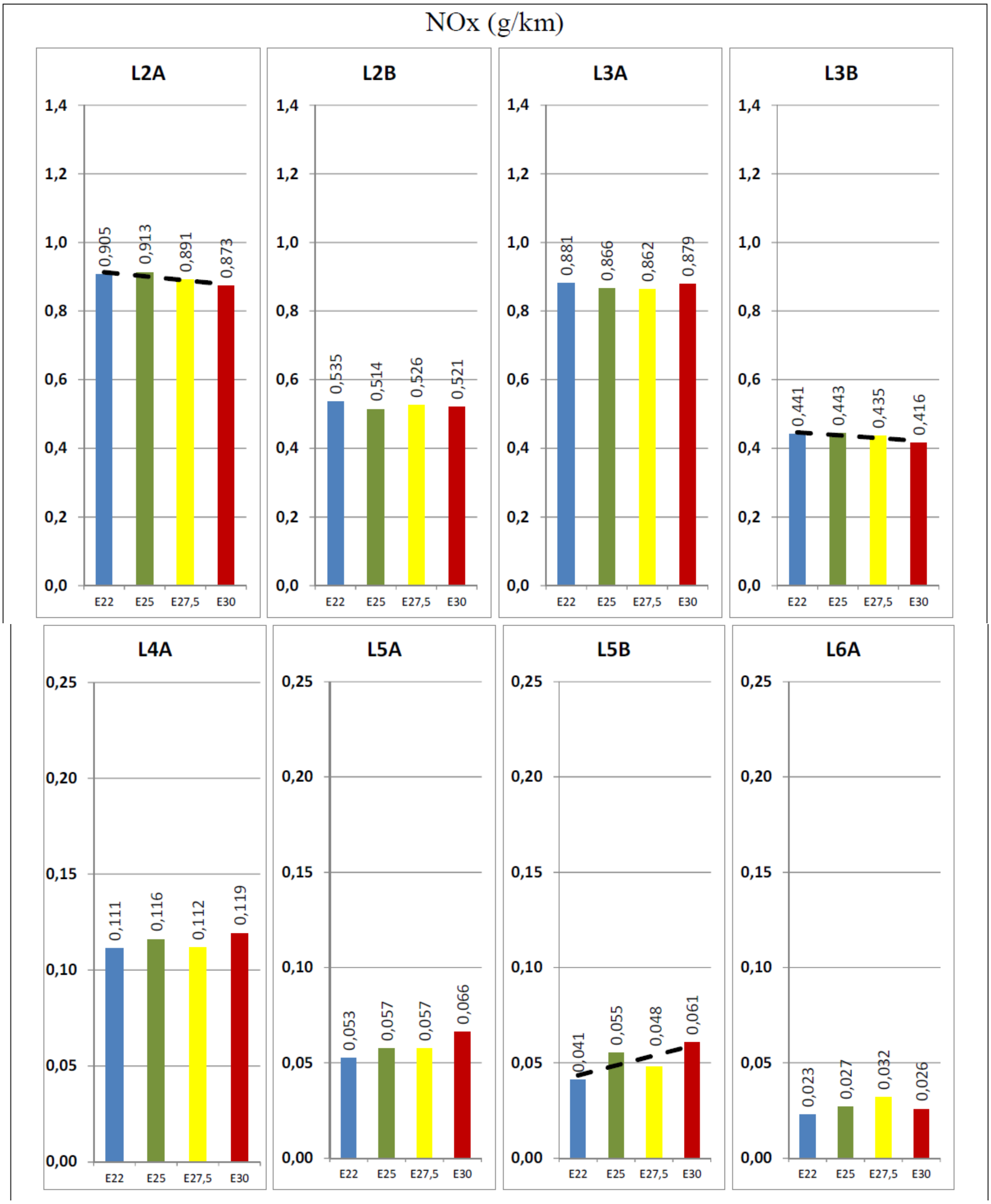
Figure 3 - THC (L2, L3) and NMHC (L4, L5 and L6) emissions



Notes: (1) PROCONVE limits for 80,000 km (g/km): L2= 12.0, L3=2.0, L4=2.0, L5=2.0, L6=1.3

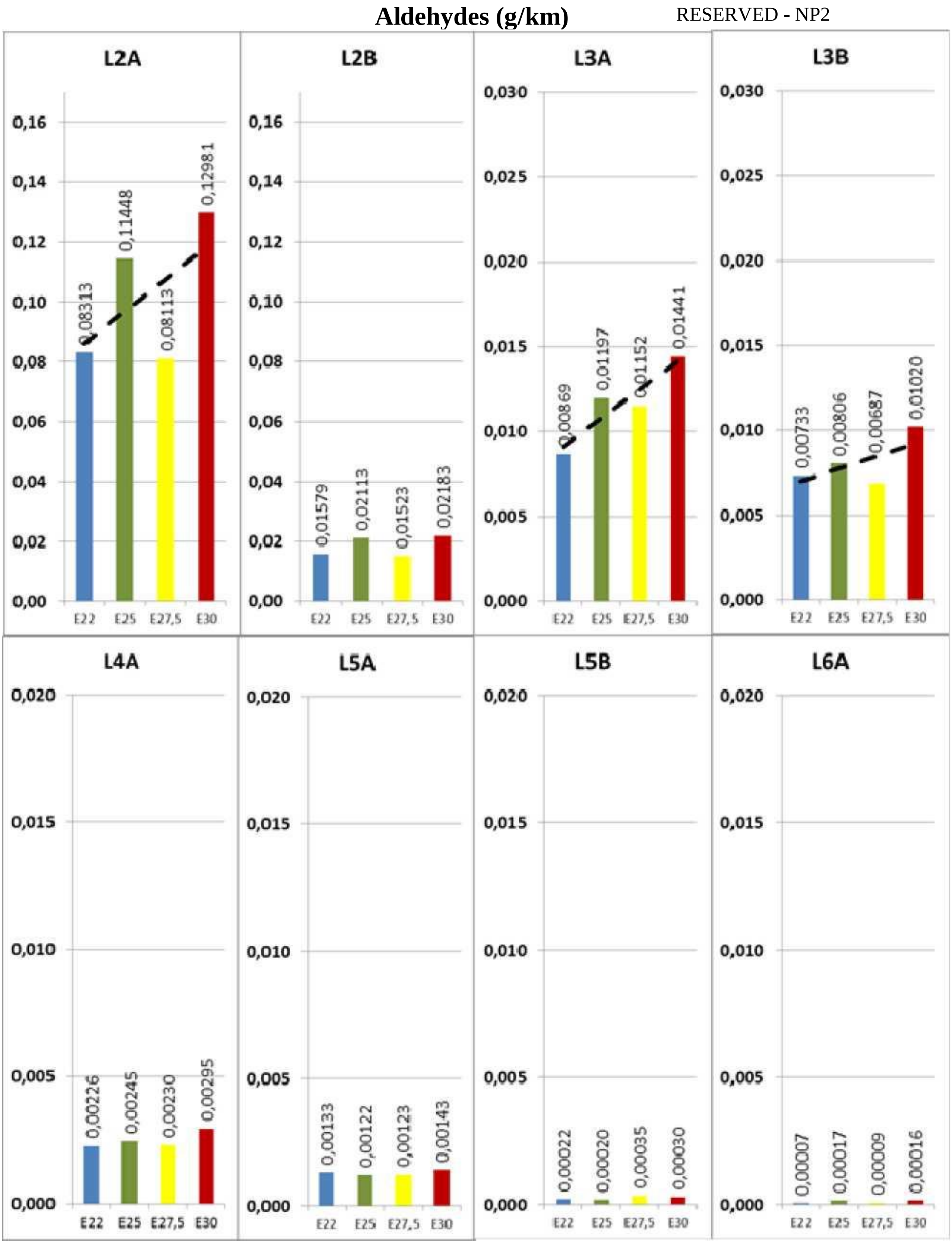
(2) The regression models of the L3A, L3B, L5B e L6A vehicles were not presented because ANOVA did not indicate that the influence of the fuel is significant at a level $p < 0.05$.

Figure 4 - CO emissions in tested automobiles



Notes: (1) PROCONVE limits for 80,000 km (g/km): L2 = 2.0, L3 = 0.6, L4 = 0.25, L5 = 0.12, L6 = 0.08.
(2) The regression models of the L2B, L3A, L4A, L5A and L6A vehicles were not presented because ANOVA did not indicate that the influence of the fuel is significant at a level $p < 0.05$.

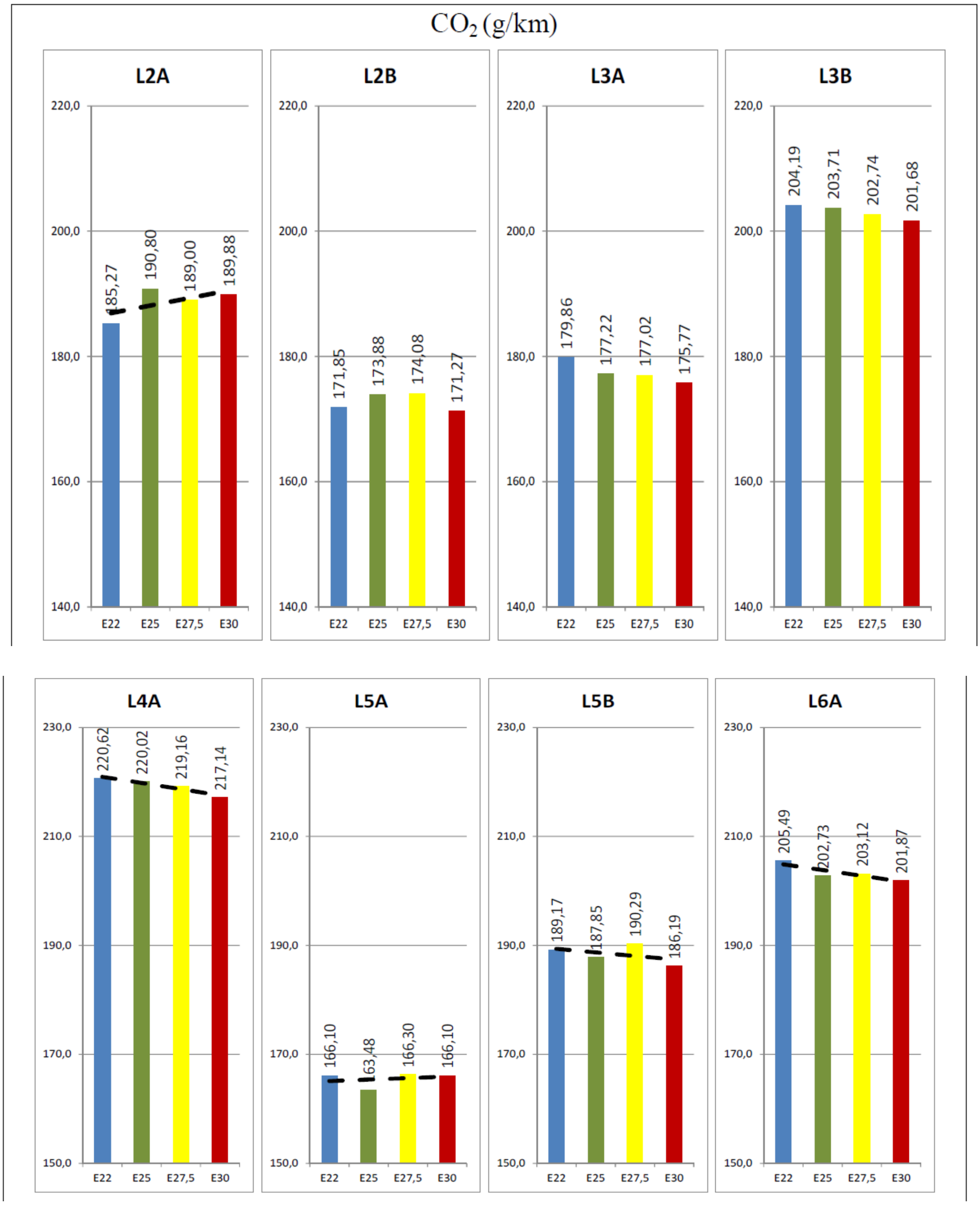
Figure 5 - NOx emissions (g/km) in the tested automobiles



Notes: (1) PROCONVE limits for 80,000 km (g/km): L2 = 0.15, L3 = 0.03, L4 = 0.03, L5 = 0.03, L6 = 0.02.

(2) The regression models of the L2B, L4A, L5A, L5B and L6A vehicles were not presented because ANOVA did not indicate that the influence of the fuel is significant at a level p <0.05.

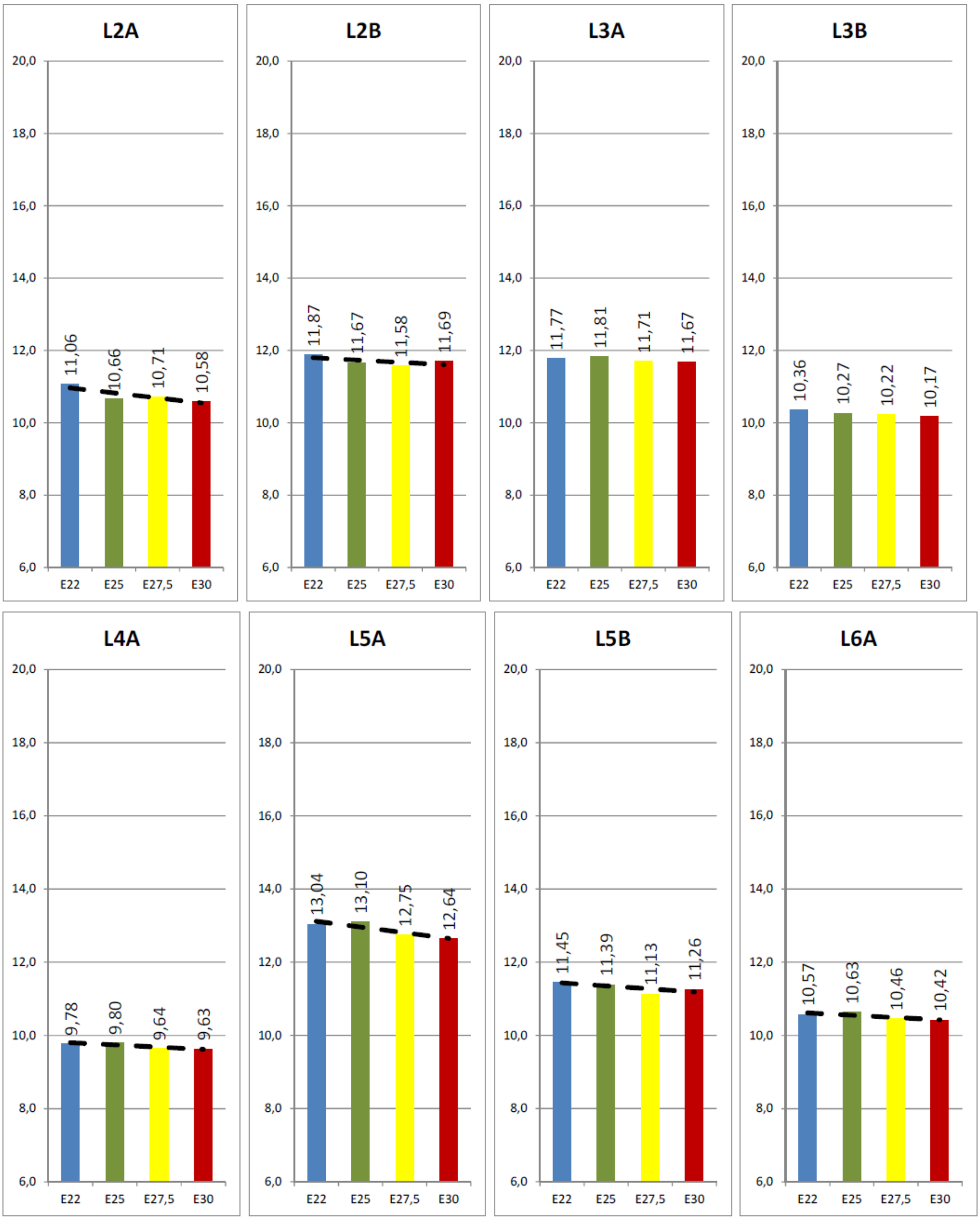
Figure 6- Aldehyde emissions (g/km) in the tested automobiles.



Note: The regression models of the L2B, L3A and L3B vehicles were not presented because ANOVA did not indicate that the influence of the fuel is significant at a level $p < 0.05$.

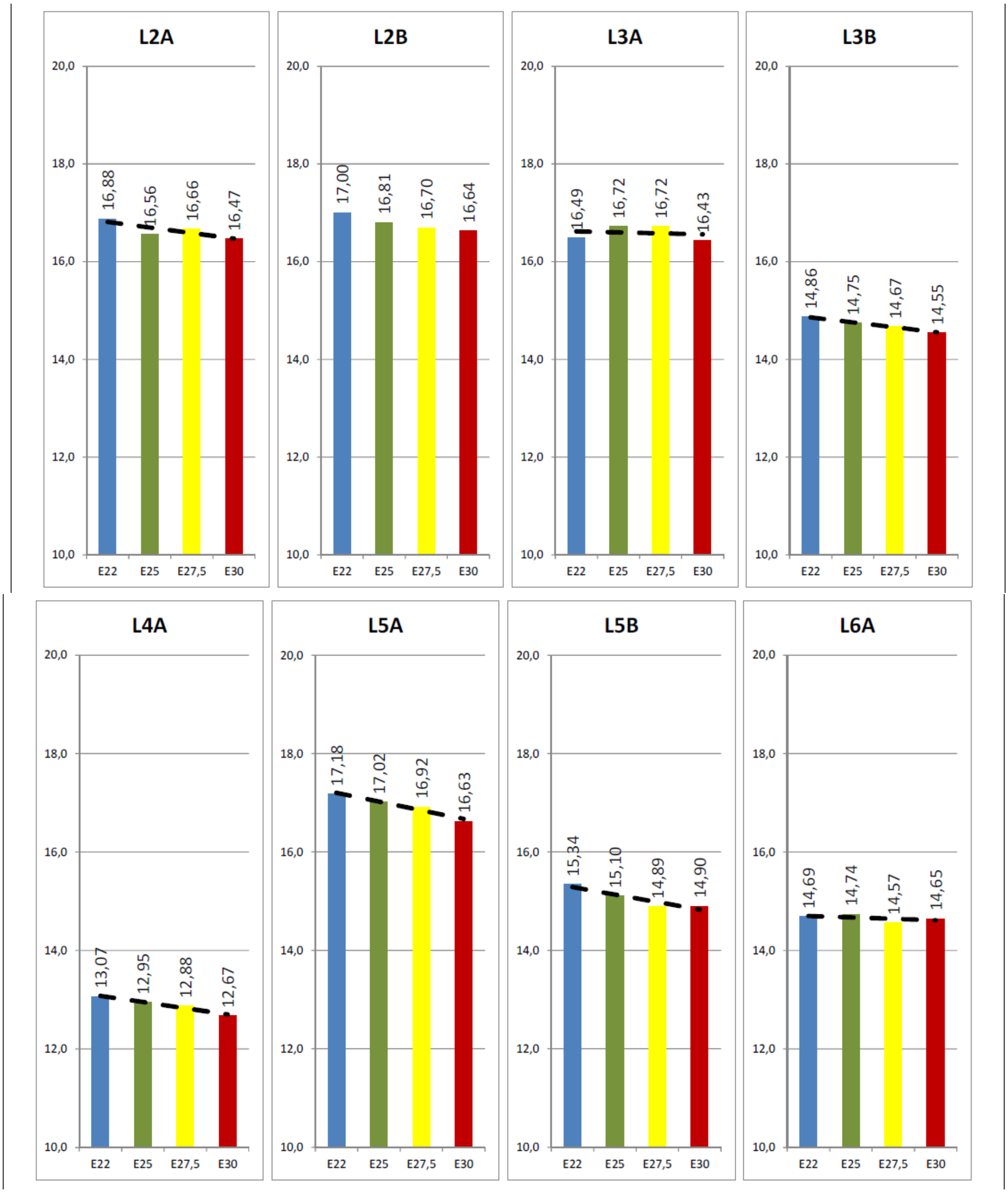
Figure 7- CO2 emissions (g/km) in the tested automobiles.

"City" Fuel Economy (km/L)



Note: The regression models of the L3A and L3B vehicles were not presented because ANOVA did not indicate that the influence of the fuel is significant at a level $p < 0.05$.

Figure 8- City fuel economy (km/l) in the tested cars.



Note: The regression models of the L2A vehicles were not presented because ANOVA did not indicate that the influence of the fuel is significant at a level $p < 0.05$.

Figure 9- Highway fuel economy (km / l) in the tested automobiles.

In a qualitative analysis of the trends indicated by the graphs, in general, it is observed that, with the increase in ethanol content between the levels of 22 and 30% v/v, there is 'no change' or 'reduction' in the emissions of hydrocarbon (THC and NMHC), CO and CO2. For this latter gas, however, there was an exception (trend towards an increase in the L2A vehicle).
The NOx of the older vehicles (L2 and L3) also follows the 'no change' or 'reduction' trends, but for the newer ones (L4 vehicles and beyond), this does not occur. In these cases, it was found that there was a trend towards an increase in one vehicle (L5B), while for the others (L4A, L5A and L6A), it cannot be said that the fuel had a statistically significant influence on the pollutant emission level. However, it is worth noting that, in the case in which there was NOx elevation, the highest value found (the L5B vehicle with E30) was 45% below the PROCONVE limit for this pollutant.

For aldehydes, there was a trend of increased emissions in some vehicles. For them, the highest emission found (L5A with E30) was 95% below the PROCONVE limit.

For fuel economy (in the city and on highways), there is a trend of reduction in all vehicles.

The observed trends confirm the expectations, since the use of fuels with higher ethanol content tends to impoverish the air-fuel mixture, which in general leads to a lower emission of hydrocarbons (THC and NMHC) and CO, but eventually also causes an increase in NOx and aldehydes, in addition to a reduction in fuel economy, in this case due to the lower energy content of ethanol.

This behavior is most striking in vehicles with old technologies, represented in this work by 'PROCONVE L2 Phase' cars, which normally work on a 'rich mixture' (that is, with excess fuel) ratio basis. In newer vehicles, the emission control system is designed to work most of the time in the stoichiometric region of the air-fuel mixture. Therefore, small variations in the oxygen content of the fuel can be corrected by the system and end up having a small impact on the emissions.

However, even in these vehicles, during a cold start, a rich mixing regime is used temporarily to avoid malfunctions during the heating of the engine. In this situation, since the catalytic converter of the vehicle has not yet reached its maximum efficiency temperature, the use of a fuel that has a higher oxygen content may momentarily lead to the same trends discussed above.

In order to ascertain which differences could be considered statistically significant in relation to the fuel with which the vehicles were approved (E22) and the gasoline currently marketed (E25), a comparison was made of the results obtained from the regression lines, as described in item 4.1.2. It should be noted that, in many cases, even though a trend towards the variation with the ethanol content was identified, the error associated with the regression did not allow to find a statistically significant difference between the fuels, in the comparison ranges of interest.

Comparison with E22

Tables IV to VI show the comparison of fuels E25, E27.5 and E30 with the E22 reference. When the use of the ANOVA technique indicated beforehand that the influence of the fuel was not significant, the "no diff." code was written. Where it was considered significant, the emission or fuel economy was calculated based on the respective regression lines, in addition to the corresponding confidence intervals. When the confidence intervals of the values being compared overlapped, "no diff." was put again. In cases in which this did not occur, the percentage difference between the estimated values was calculated, and the negative sign before the value indicates a reduction in the emission or fuel economy. For better visualization, results that represent an improvement in the attribute are highlighted in green, while worse results are in red.

Table IV - Comparison between emissions and fuel economy with E25 and E22.

E25x E22								
Vehicles	L2A	L2B	L3A	L3B	L4A	L5A	L5B	L6A
THC (L2, L3) & NMHC (L4, L5, L6)	no diff.	no diff.	no diff.	no diff.	no diff.	no diff.	no diff.	no diff.
CO	-11%	-9%	no diff.	no diff.	no diff.	no diff.	no diff.	no diff.
NOx	no diff.	no diff.	no diff.	no diff.	no diff.	no diff.	no diff.	no diff.
Aldehydes	no diff.	no diff.	no diff.	no diff.	no diff.	no diff.	no diff.	no diff.
CO_2	no diff.	no diff.	no diff.	no diff.	no diff.	no diff.	no diff.	no diff.
"City" Fuel Economy	no diff.	no diff.	no diff.	no diff.	no diff.	no diff.	no diff.	no diff.
Highway Fuel Economy	no diff.	no diff.	no diff.	-1%	-1%	no diff.	no diff.	no diff.

Table V- Comparison between emissions and fuel economy with E27.5 and E22.

E27.5 x E22								
Vehicles	L2A	L2B	L3A	L3B	L4A	L5A	L5B	L6A
THC (L2, L3) & NMHC (L4, L5, L6)	no diff.	no diff.	no diff.	no diff.	no diff.	no diff.	no diff.	no diff.
CO	-21%	-16%	no diff.	no diff.	-10%	no diff.	no diff.	no diff.
NOx	no diff.	no diff.	no diff.	no diff.	no diff.	no diff.	no diff.	no diff.
Aldehydes	no diff.	no diff.	39%	no diff.	no diff.	no diff.	no diff.	no diff.
CO_2	no diff.	no diff.	no diff.	no diff.	-1%	no diff.	no diff.	-1%
"City" Fuel Economy	-3%	no diff.	no diff.	no diff.	-1%	-2%	no diff.	no diff.
Highway Fuel Economy	-1%	no diff.	no diff.	-1%	-2%	-2%	-2%	no diff.

Table VI - Comparison between emissions and fuel economy with E30 and E22.

E30x E22								
VEHICLE	L2A	L2B	L3A	L3B	L4A	L5A	L5B	L6A
THC (L2, L3) & NMHC (L4, L5, L6)	no diff.	-10%	no diff.	no diff.	no diff.	-27%	no diff.	no diff.
CO	-31%	-23%	no diff.	no diff.	-15%	no diff.	no diff.	no diff.
NOx	no diff.	no diff.	no diff.	-6%	no diff.	no diff.	no diff.	no diff.
Aldehydes	no diff.	no diff.	57%	no diff.	no diff.	no diff.	no diff.	no diff.
CO_2	no diff.	no diff.	no diff.	no diff.	-2%	no diff.	no diff.	-2%
"City" Fuel Economy	-4%	no diff.	no diff.	no diff.	-2%	-3%	-2%	-2%
Highway Fuel Economy	-2%	no diff.	no diff.	-2%	-3%	-3%	-3%	no diff.

Table IV indicates a trend towards the reduction in CO in the exhaust of the older vehicles (2 had a reduction of up to 11%), but, for the others, the differences found were not statistically significant.

With respect to fuel economy, it was possible to detect a decrease in the results in the highway fuel economy (1%) only in 2 vehicles.

In the comparison of the results obtained with E27.5 and E22 (Table V), it was observed that, in general, the addition of a greater content of ethanol led to changes similar to those observed in the comparison between E25 and E22.

The emission of CO continued to decrease, but the reduction was steeper (up to 21%) and the newer vehicles were also affected. With respect to the emission of CO_2, there was a reduction in 2 vehicles (1%). No significant changes were found for NMHC and NOx, while for aldehydes an increase was detected in an isolated case (39% in 1 vehicle).

With respect to fuel economy, the reduction was statistically significant in 5 of the 8 vehicles tested, with variations of around 2%.

As shown in Table VI, in addition to the reduction in CO (up to 31% in 3 vehicles) and CO2 (2% in 2 vehicles), the addition of 30% ethanol to gasoline resulted in a reduction in the emission of hydrocarbons (up to 27% in 2 vehicles) and NOx (6% in 1 vehicle). However, there was a more marked increase in the emission of aldehydes (57% in 1 vehicle). The decrease in fuel economy was higher than that observed with the use of E27.5 (up to 4% in 6 vehicles).

Comparison with E25

Tables VII and VIII present the comparison of the results obtained in the models using E27.5 and E30 with those using E25.

Table V- Comparison between emissions and fuel economy with E27.5 and E25.

E27.5 x E25								
VEHICLE	L2A	L2B	L3A	L3B	L4A	L5A	L5B	L6A
THC (L2, L3) & NMHC (L4, L5, L6)	no diff.	no diff.	no diff.	no diff.	no diff.	no diff.	no diff.	no diff.
CO	-11%	-8%	no diff.	no diff.	no diff.	no diff.	no diff.	no diff.
NOx	no diff.	no diff.	no diff.	no diff.	no diff.	no diff.	no diff.	no diff.
Aldehydes	no diff.	no diff.	no diff.	no diff.	no diff.	no diff.	no diff.	no diff.
CO_2	no diff.	no diff.	no diff.	no diff.	no diff.	no diff.	no diff.	no diff.
"City" Fuel Economy	no diff.	no diff.	no diff.	no diff.	no diff.	no diff.	no diff.	no diff.
Highway Fuel Economy	no diff.	no diff.	no diff.	-1%	-1%	no diff.	no diff.	no diff.

Table V- Comparison between emissions and fuel economy with E30 and E25.

E30x E25								
VEHICLE	L2A	L2B	L3A	L3B	L4A	L5A	L5B	L6A
THC (L2, L3) & NMHC (L4, L5, L6)	no diff.	no diff.	no diff.	no diff.	no diff.	no diff.	no diff.	no diff.
CO	-22%	-16%	no diff.	no diff.	-10%	no diff.	no diff.	no diff.
NOx	no diff.	no diff.	no diff.	no diff.	no diff.	no diff.	no diff.	no diff.
Aldehydes	no diff.	no diff.	no diff.	no diff.	no diff.	no diff.	no diff.	no diff.
CO_2	no diff.	no diff.	no diff.	no diff.	-1%	no diff.	no diff.	-1%
"City" Fuel Economy	-2%	no diff.	no diff.	no diff.	no diff.	-2%	no diff.	no diff.
Highway Fuel Economy	-1%	no diff.	no diff.	-1%	-2%	-2%	-2%	no diff.

Table VII indicates a very similar result to that observed in the E25 x E22 comparison (table IV) with changes statistically significant only for CO (up to 11% in 2 vehicles) and fuel economy (reduction of 1% in other 2 vehicles) .

Table VIII shows that, in addition to an increase in the CO reduction (up to 22% in 3 vehicles) and fuel economy (up to 2% in 5 vehicles), the increase in ethanol content of up to 30% also led to a reduction in CO2 (1% in 2 vehicles).

4.2 MOTORCYCLES

4.2.1. Test methodology

In accordance with CONAMA Resolution number 297, published in 2002, emissions and fuel-economy tests in mopeds, motorcycles and the like must comply with the requirements of European Directive 97/24/EC (8), in which the test vehicle is subjected to a controlled load condition on a chassis dynamometer (figure10).

Figure 10 - Motorcycle installed for exhaust emission testing at Lactec.

As is the case for light vehicles, exhaust gases emitted in each stage of the dynamometric test are diluted in ambient air, collected and stored in flasks, and then quantified in specific analyzers (Figure 11). The gases measured in this test are total hydrocarbons (THC), carbon monoxide (CO), carbon dioxide (CO_2) and nitrogen oxides (NO_x). The analytical techniques for determining these gases are the same as those used in light vehicle tests.

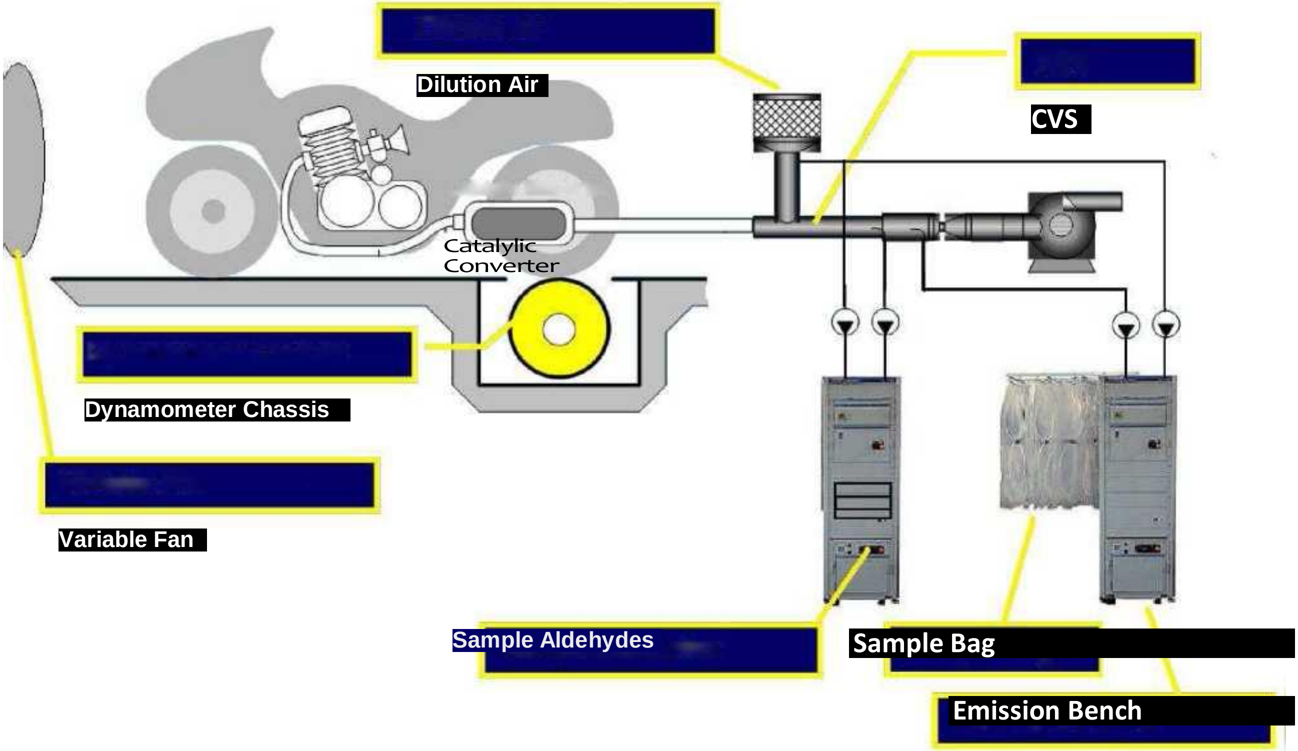


Figure 11 - Scheme of sample collection for the test of emissions in motorcycles.

To allow a better sensitivity of the statistical analysis of the data, at least three tests are also performed for each one of the conditions.

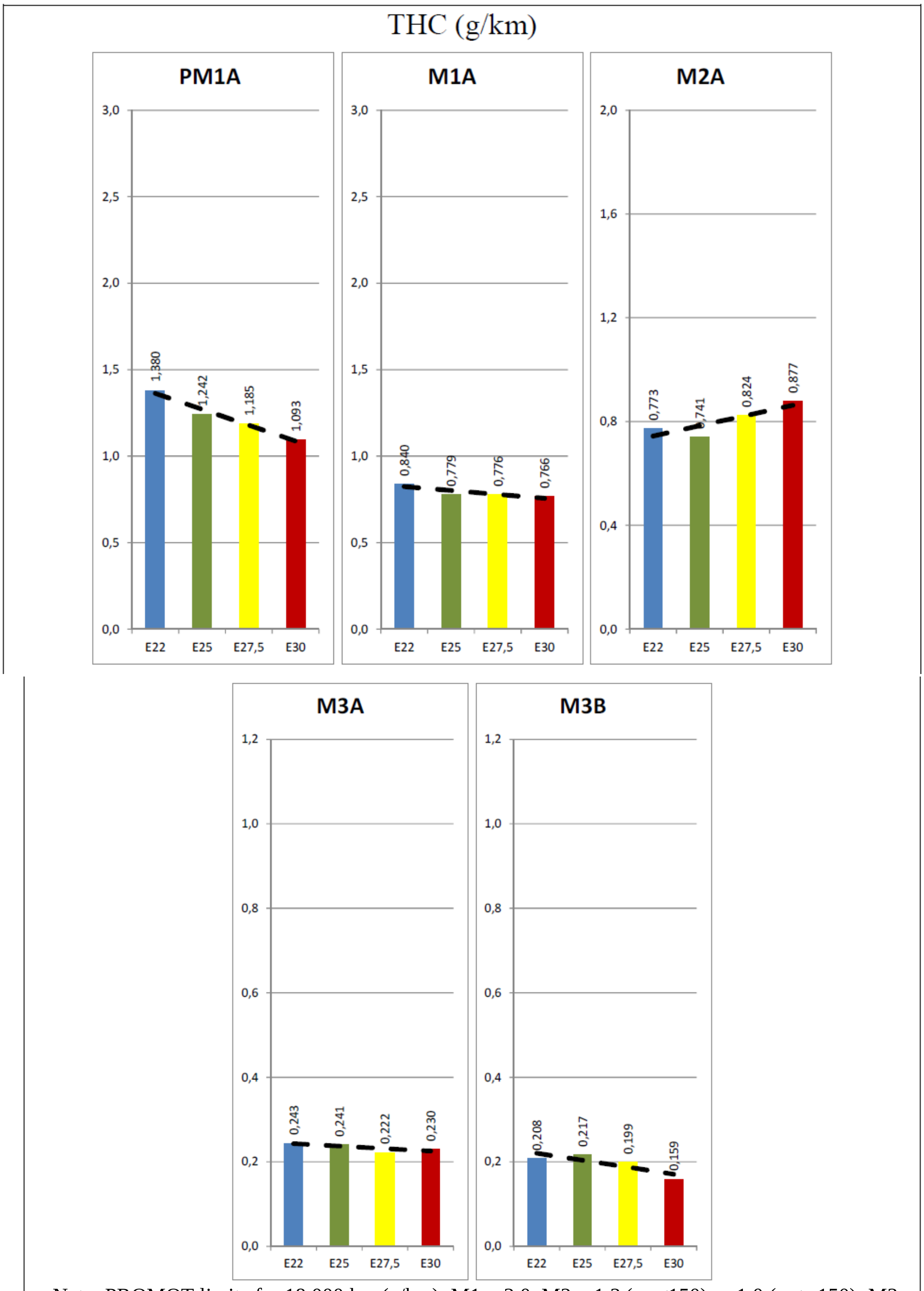
4.2.2. Methodology for Statistical Analysis

For processing the data and analyzing the results obtained with the motorcycles tested, the same methodology used for the vehicles was used, as described in item 4.1.2. The graphs resulting from the Regression Analysis that was performed are listed in Annex III.

4.2.3. Results and Discussion

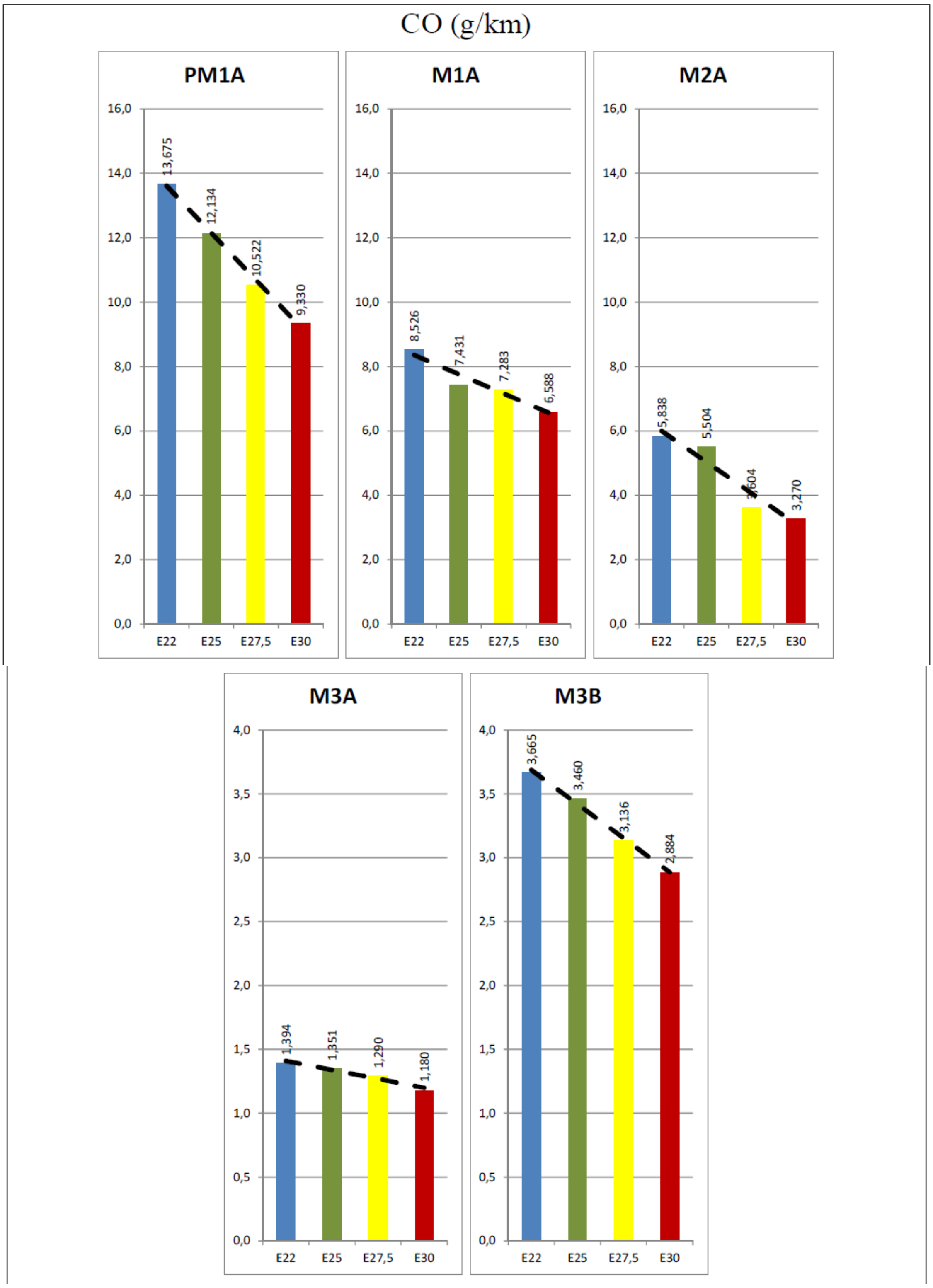
Figures 12 to 16 show the mean values of the results obtained in the exhaust emission and fuel-economy tests, as well as the regression line that was fitted, only in cases where the Variance Analysis indicated that there was significant influence of the fuel. They also indicate the PROMOT limit for 18,000 km.

Annex III shows graphs with the experimental points, regression lines and curves of the error inherent in the fit. In the same Annex, there is a table with the values of the regression coefficients, as well as the estimated values for points E22, E25, E27.5 and their respective confidence intervals.



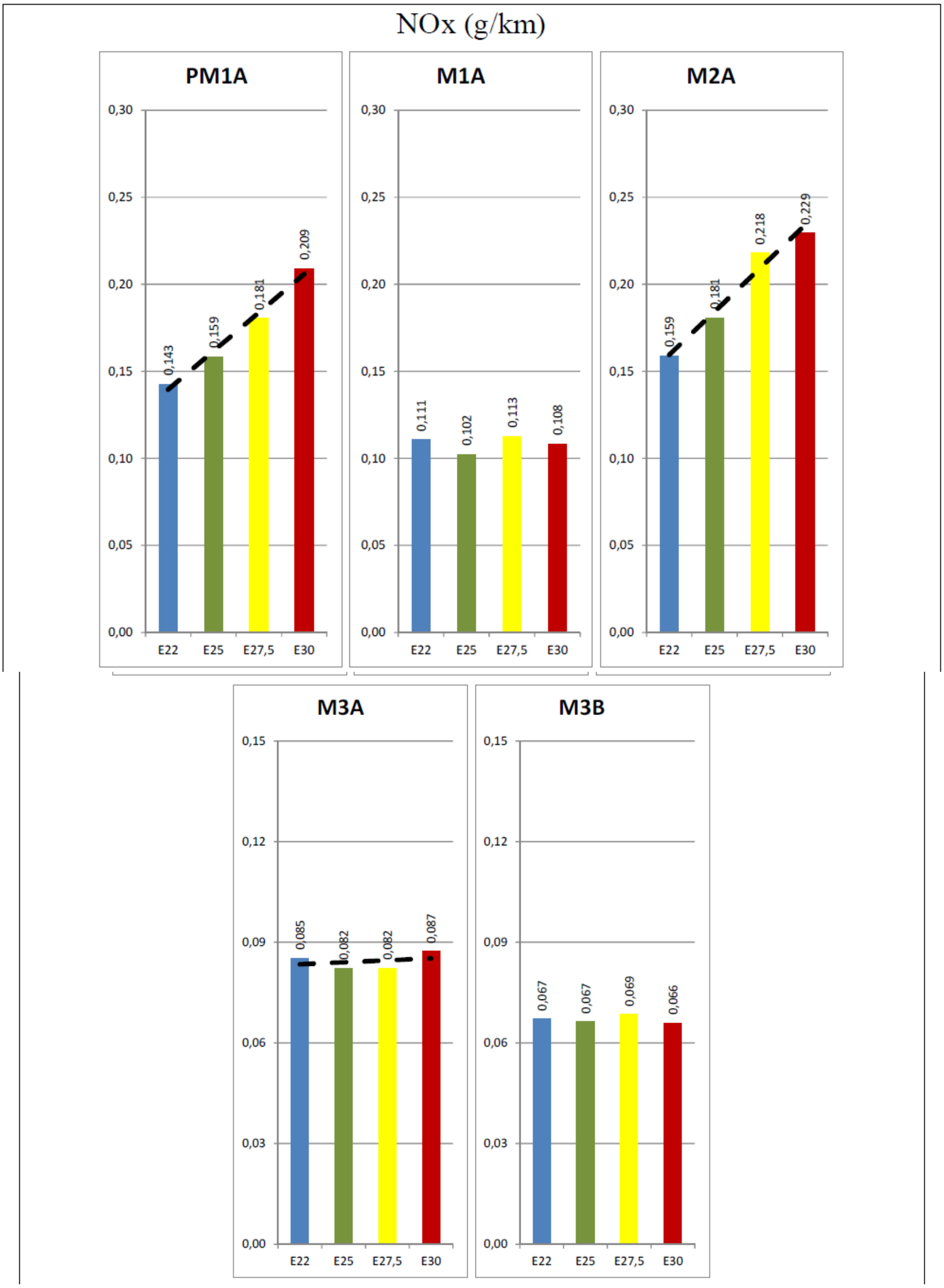
Note: PROMOT limits for 18,000 km (g/km): M1 = 3.0, M2 = 1.2 (cc <150) or 1.0 (cc > 150), M3 = 0.8 (cc <150) or 0.3 (cc > 150).

Figure 12- THC emissions in motorcycles.



Note: PROMOT limits for 18,000 km (g/km): M1 = 13.0, M2 = 5.5, M3 = 2.0.

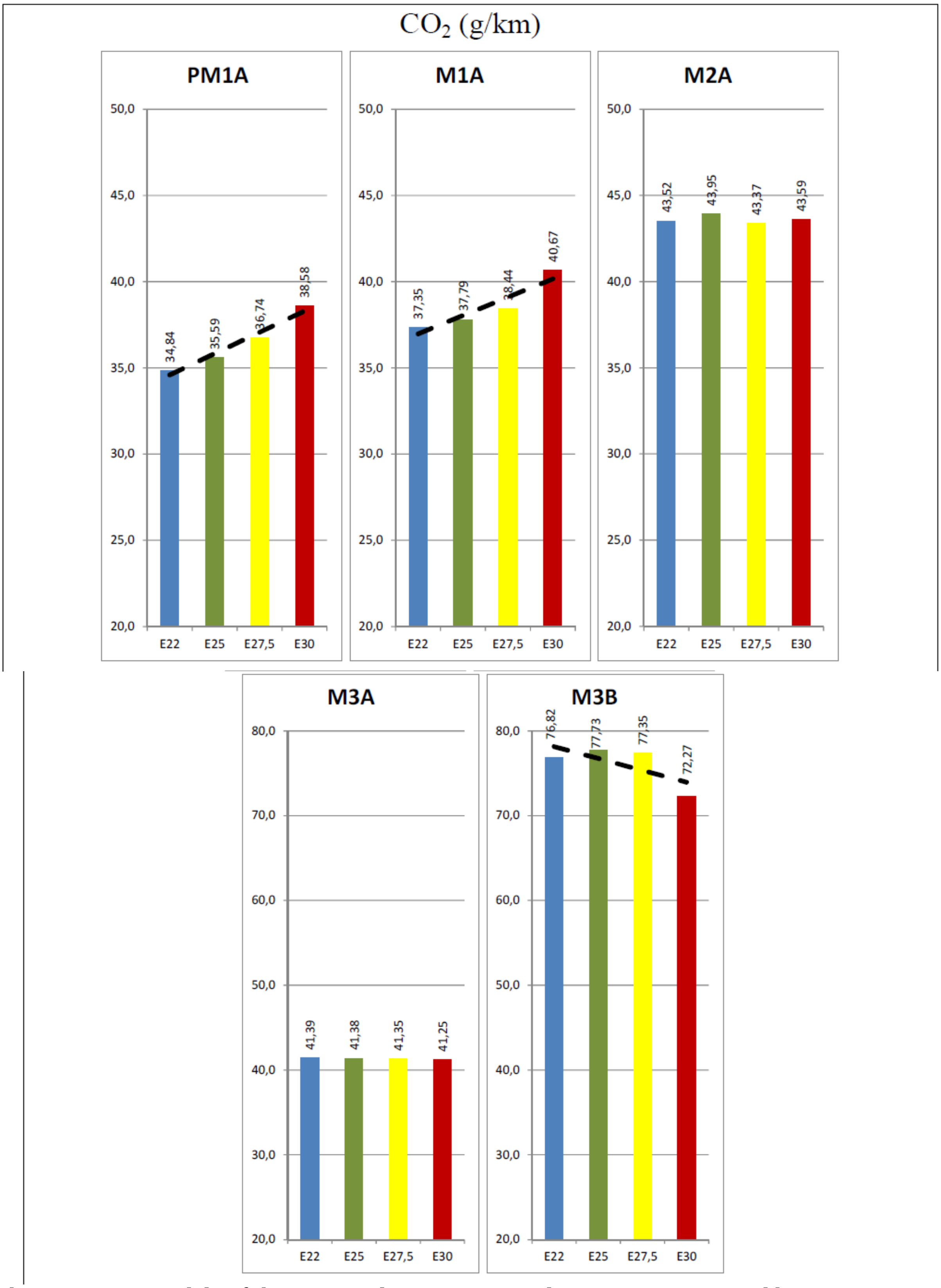
Figure 13 - CO emissions in motorcycles.



Notes: (1) PROMOT limits for 18,000 km (g/km): M1 = 0.3, M2 = 0.3, M3 = 0.15.

(2) The regression models of the M1A and M3B motorcycles were not presented because ANOVA did not indicate that the influence of the fuel is significant at a level $p < 0.05$.

Figure 14 - Emissions of NOx in motorcycles.



Note: The regression models of the M2A and M3A motorcycles were not presented because ANOVA did not indicate that the influence of the fuel is significant at a level $p < 0.05$.

Figure 15 - Emissions of CO_2 in motorcycles.

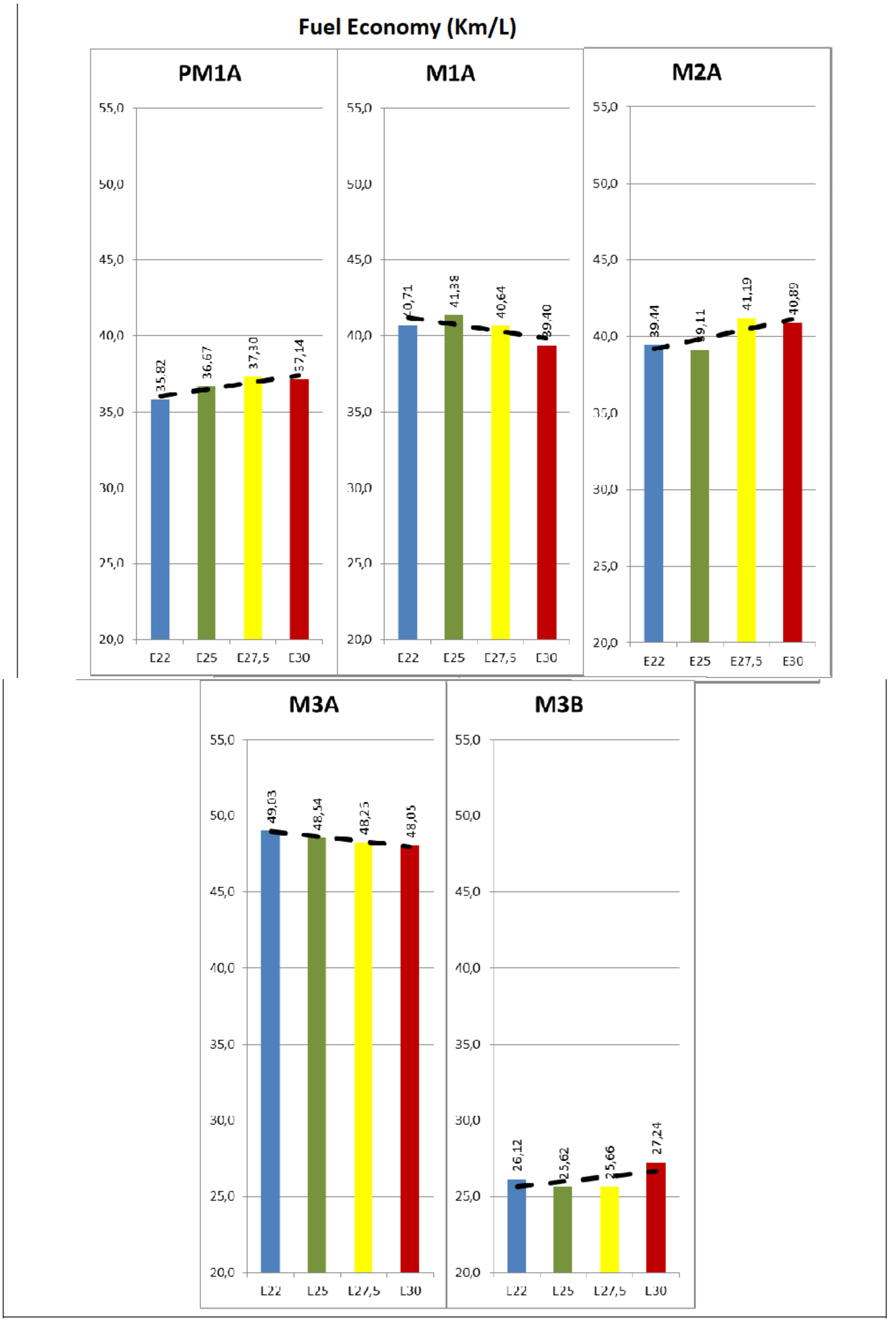


Figure 16 - Fuel economy in the motorcycles.

Of the bikes tested, only those of the M3 phase had been ridden for less than 18,000 km and for that reason their emissions
were compared to their respective PROMOT limits. It was found that both were within
all the limits, except for the CO in M3B. It should be noted that this M3B motorcycle was within the limits of inspection and maintenance emission and did not show any functional anomalies.

Like for the cars, there is a trend towards the reduction in emissions of THC and CO (except for THC in M2A) that follows the increase in ethanol content.

For the NOx emission, there was a trend towards an increase in three of the tested motorcycles (PM1A, M2A and M3A) and no trend in the others. However, it is worth noting that, for the M3A motorcycle, which was still obliged to comply with the PROMOT emission limits due to its odometer reading, the highest value found (E30) was 42% below the established value.

For the emissions of CO2, there was no definite trend (trends towards an increase in PM1A and M1A and reduction in M3B). There was no trend for fuel economy either (reduction in M1A, M2A and M3A and increase in PM1A and M3B). With respect to this last attribute, the behavior is different from that of the vehicles, in which the trend was always towards the reduction. This situation can be explained by the fact that motorcycles up to the M3 phase of PROMOT generally operate with a very rich Air-Fuel Ratio (AFR). Thus, the use of a fuel with higher oxygen content tends to bring the AFR closer to the stoichiometric ratio, resulting in improved fuel economy. However, for motorcycles that do not operate with such rich AFR, this effect may be less important, and it is then outweighed by the lower calorific value of mixtures that use higher ethanol content.

Comparison with E22

Tables IX to XI show the comparison of fuels E25, E27.5 and E30 with the E22 reference. When the use of the ANOVA technique indicated beforehand that the influence of the fuel was not significant, the "no diff." code was written. Where it was considered significant, the emission or fuel economy was calculated based on the respective regression lines, in addition to the corresponding confidence intervals. When the confidence intervals of the values being compared overlapped, "no diff." was written again. In cases in which this did not occur, the percentage difference between the estimated values was calculated, and the negative sign before the value indicates a reduction in the emission or driving range. For better visualization, results that represent an improvement in the attribute are highlighted in green, while worse results are in red.

Table IX - Comparison between emissions and fuel economy with E25 and E22.

E25x E22					
Motorcycles	PM1A	M1A	M2A	M3A	M3B
THC	-8%	no diff.	no diff.	no diff.	no diff.
CO	-12%	-8%	-18%	no diff.	-8%
NOx	18%	no diff.	18%	no diff.	no diff.
CO_2	4%	no diff.	no diff.	no diff.	no diff.
Fuel economy	no diff.	no diff.	no diff.	-1%	no diff.

Table X - Comparison between emissions and fuel economy with E27.5 and E22.

E27.5 x E22					
Motorcycles	PM1A	M1A	M2A	M3A	M3B
THC	-14%	no diff.	no diff.	no diff.	-15%
CO	-22%	-15%	-33%	-10%	-15%
NOx	33%	no diff.	32%	no diff.	no diff.
CO_2	7%	6%	no diff.	no diff.	no diff.
Fuel economy	3%	no diff.	no diff.	-1%	no diff.

Table XI - Comparison between emissions and fuel economy with E30 and E22.

E30x E22					
Motorcycles	PM1A	M1A	M2A	M3A	M3B
THC	-20%	-8%	no diff.	no diff.	-22%
CO	-32%	-22%	-48%	-15%	-22%
NOx	48%	no diff.	47%	no diff.	no diff.
CO_2	11%	9%	no diff.	no diff.	no diff.
Fuel economy	4%	no diff.	5%	-2%	no diff.

In the comparison between the results obtained with E25 and E22 (Table IX), it was found that there were reductions in the THC and CO emissions of 8% and 18%, respectively. However, there was a 4% increase in CO2 emission in one motorcycle (PM1A), reduction of fuel economy by 1% in M3B and increase of 18% in NOx emissions in two motorcycles (PM1A and M2A).

With the use of the E27.5 and E30 fuels, there was an accentuation of the behaviors described above (except for fuel economy), as shown in Tables X and XI.

With respect to reference E22, the use of E27.5 resulted in more marked reductions in THC and CO emissions (up to 15% and 33%, respectively), and increased NOx emissions (up to 33% on two bikes) and CO2 emissions (up to 7% in two bikes). In terms of fuel economy, the trend was undefined (1% reduction in one motorcycle and 3% increase in another).

With E30, the reductions of THC and CO emissions were of up to 22% and 48%, respectively, but there was an increase in NOx emissions by up to 48% in two motorcycles (PM1A and M2A). The differences in CO_2 and fuel economy became more accentuated, with an increase of up to 11% in the first case and an undefined trend in the second one (increase of up to 5% in two motorcycles and reduction of 2% in one).

Comparison with E25

In the comparison of the proposed contents (E27.5 and E30) with E25, it can be seen that, for both, there is a trend towards the reduction of THC and CO emissions and increase of NOx and CO2 emissions, as shown in Tables XII and XIII. The fuel-economy trend continues indefinitely, with some motorcycles getting better and some getting worse with this fuel.

Table XII - Comparison between emissions and fuel economy with E27.5 and E25

E27.5 x E25					
Motorcycles	PM1A	M1A	M2A	M3A	M3B
THC	-7%	no diff.	no diff.	no diff.	no diff.
CO	-12%	-7%	-18%	no diff.	-7%
NOx	13%	no diff.	13%	no diff.	no diff.
CO_2	3%	no diff.	no diff.	no diff.	no diff.
Fuel economy	no diff.	no diff.	no diff.	-1%	no diff.

Table XIII - Comparison between emissions and fuel economy with E30 and E25

E30x E25					
Motorcycles	PM1A	M1A	M2A	M3A	M3B
THC	-14%	no diff.	no diff.	no diff.	-15%
CO	-23%	-15%	-36%	-10%	-15%
NOx	25%	no diff.	25%	no diff.	no diff.
CO_2	6%	5%	no diff.	no diff.	no diff.
Fuel economy	2%	no diff.	no diff.	-1%	no diff.

5. ROAD PERFORMANCE TESTS

5.1. VEHICLES

5.1.1. Cold start and cold engine drivability

5.1.1.1. Test Methodology

The tests were carried out in refrigerated containers. Each test was started when the engine oil temperature reached 0°C, with a tolerance of 3°C above this temperature. Prior to each test with a new fuel the vehicles were driven for 10 km to ensure recognition of the new fuel, where applicable, and removal of the previous fuel from the system feed lines. Figure 17 shows the refrigerated containers used for the cold start and cold engine drivability tests.

Figure 17 - Refrigerated containers used in the cold start and cold engine drivability tests.

Each test consisted of the following steps, which were carried out consecutively after the start of the vehicles:

- Number of attempts to start the vehicle: limited to 5 attempts of no more than 10 seconds each;
- Observations of engine rotation failures during start-up;
- Monitoring of idle speed for 30 seconds after start;
- Free acceleration, pressing the gas pedal of the vehicle completely to the floor;
- Cold start and cold engine drivability, with the vehicles starting at idle, being accelerated by depressing the gas pedal to the floor and changing gears at 6000 rpm up to the third gear.

After the tests, a graphical analysis of the rotation profile of the motor was done in each case and the results were correlated with the driver's comments.

The data acquisition system stores information about rotation and engine oil temperature and it consists of the following devices:

- Engine 'rotation speed' measuring device - Tachometer;
- National Instruments (NI) data acquisition system, consisting of:

  Chassis CDAQ-9178;

  Analog input module for NI 9211 thermocouple;

  Module for analog input of voltage - NI 9219.

The tachometer is responsible for collecting and filtering information about the rotation of the engine via the inductive pickup (spark plug signal) or coil firing command signal. The equipment converts the rotation signal into a voltage output.

Using the Labview software from the National Instruments company, a program was developed to acquire data from two channels at a 10Hz acquisition rate. One of the channels is the one of oil temperature, which is measured with a J-type thermocouple, and the other is the one of voltage, which is proportional to the engine rotation speed. This software communicates with the NI hardware consisting of the base with TCP-IP communication, an analog temperature data input card (NI 9211), and an analogue voltage input card (NI 9219). The software stores the data in a text file with columns containing the time, rotation speed and temperature. Figure 18 shows the operation panel of the software.

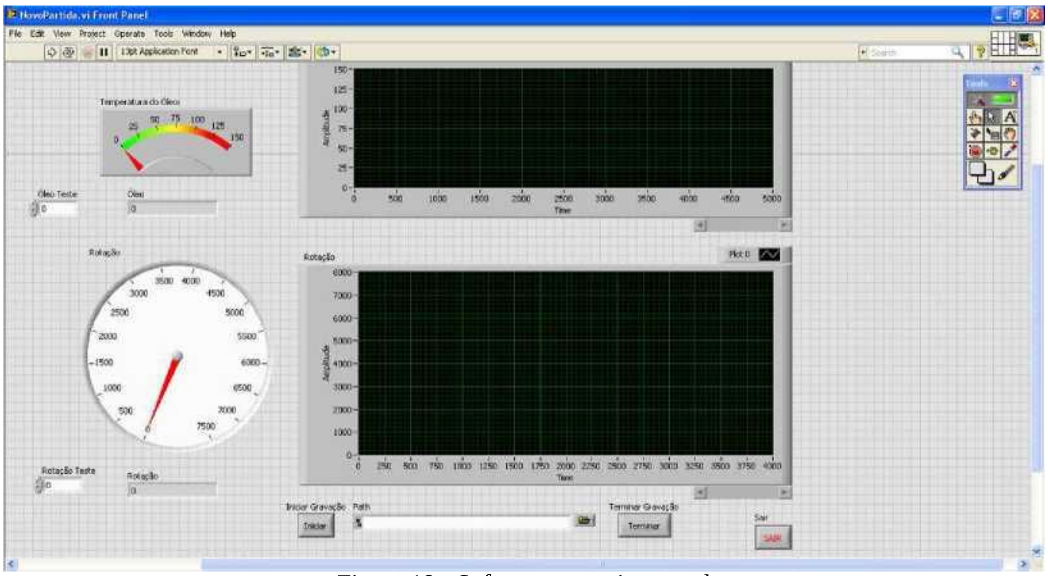


Figure 18 - Software operation panel

Results and Discussion

Figure 16 shows a typical result of the engine rotation profile during the cold start and cold engine drivability test. In it, the start-up, idle speed and free acceleration steps are highlighted. There was high noise in the signal of the records of engine rotation during the cold start and cold engine drivability step, so the use of such records for evaluating the results was not appropriate. The comments made by the driver of the vehicle were taken into consideration for the assessment of this step.

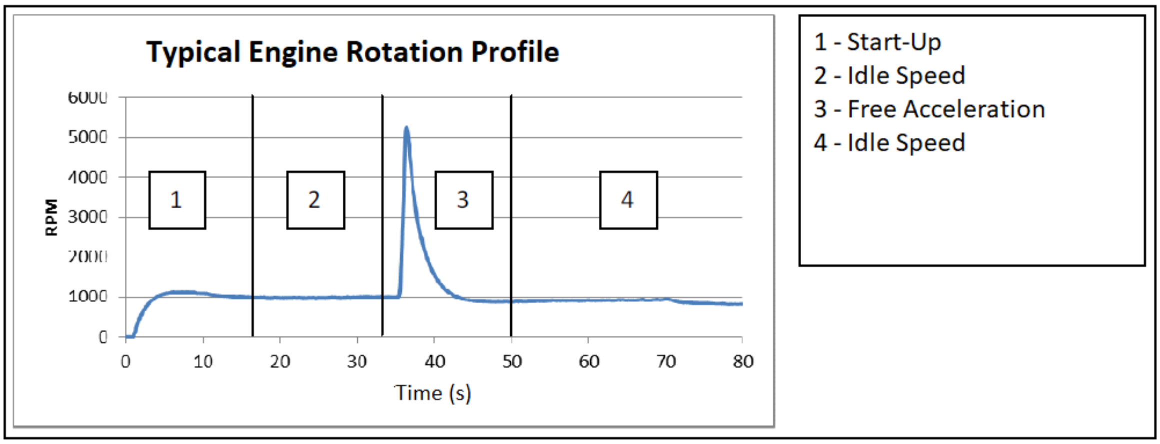


Figure 19 - Typical rotation profile of the engine during the start, idle speed and free acceleration steps

Figures 20 to 25 below show the rotation profile of the engine for six test vehicles during the start-up, idle speed and free acceleration steps. In the L5A and L6B vehicles, it was not possible to record the engine rotation because the characteristics of the engines were not compatible with the data acquisition system. To evaluate the behavior of these vehicles, the driver comments were considered for all steps of the test.

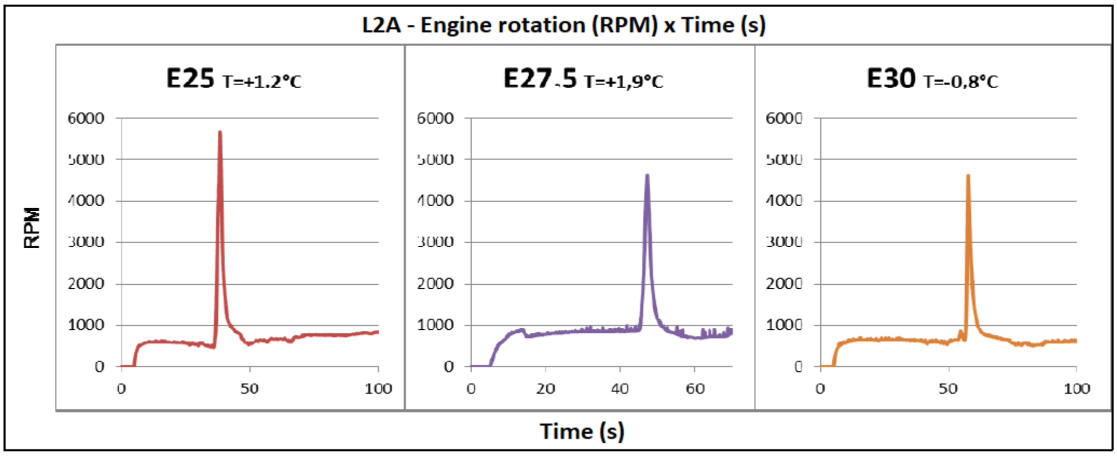


Figure 20 - Chart showing the engine rotation speed x time of the L2A vehicle with E25, E27.5 and E30.

L2B - Engine Rotation Speed (RPM) x Time (s)

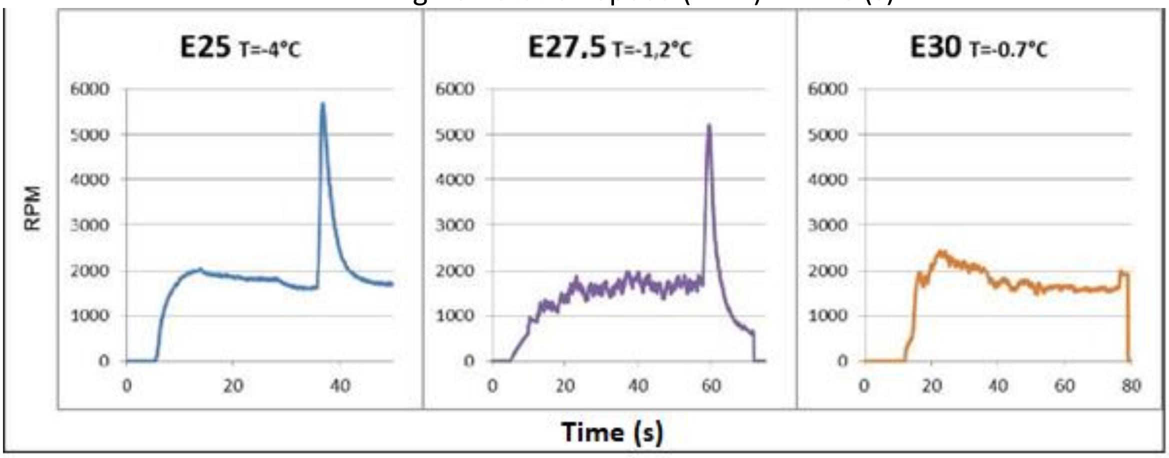
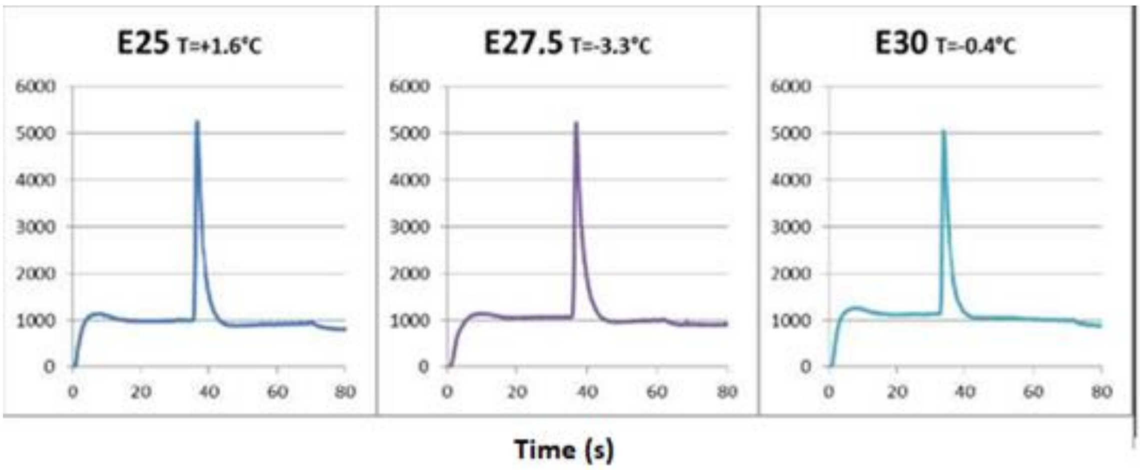


Figure 21 - Chart showing the engine rotation speed x time of the L2B vehicle with E25, E27.5 and E30.

L3A - Engine rotation speed (RPM) x Time (s)



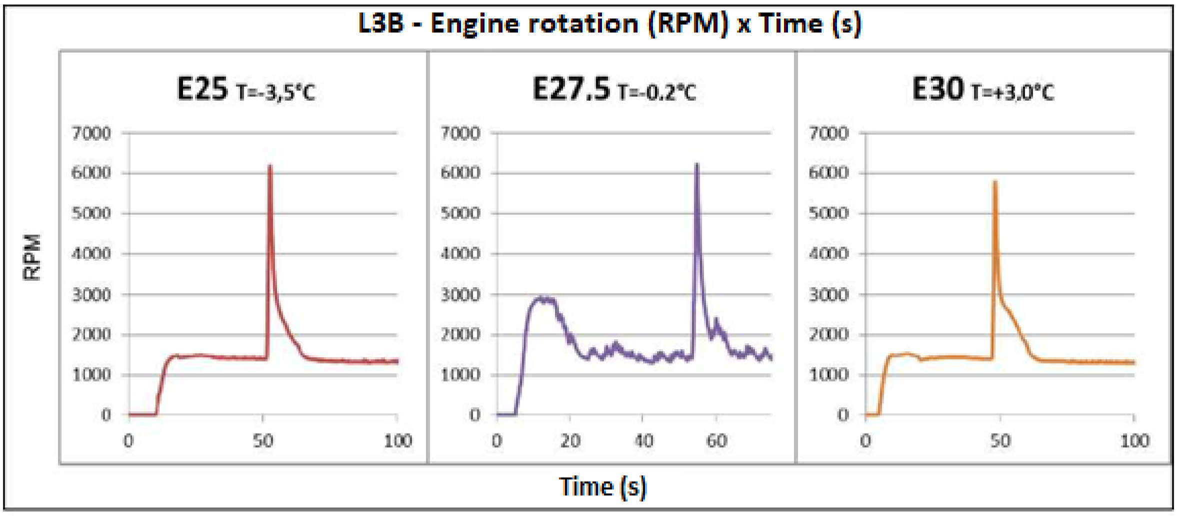


Figure 23 - Chart of engine rotation X time of the L3B vehicle with E25, E27.5 and E30.

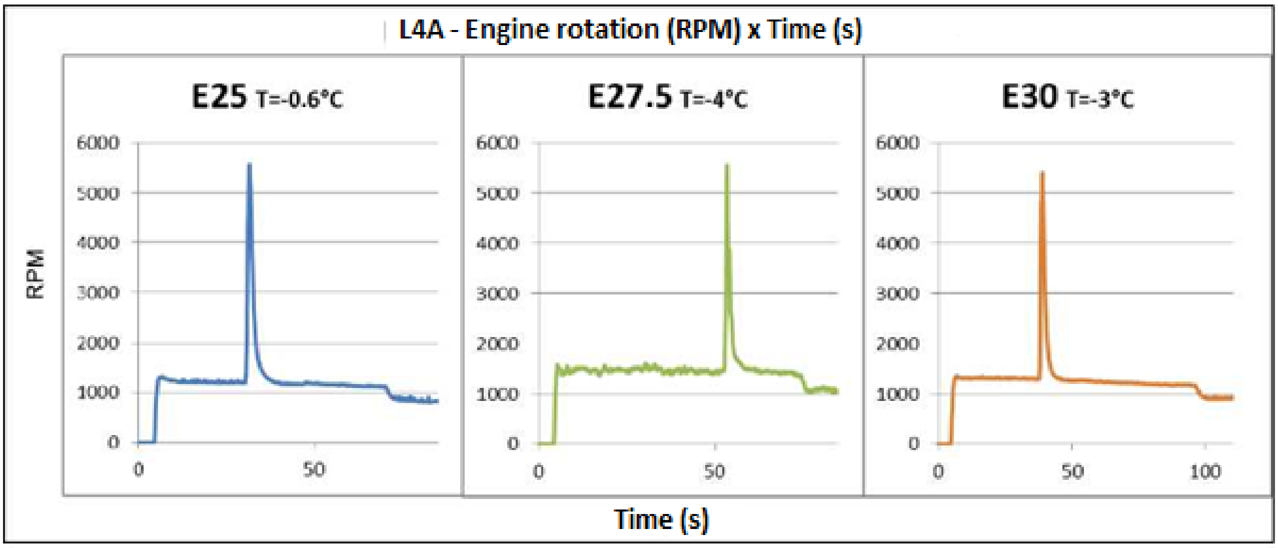


Figure 24 - Chart showing the engine rotation speed x time of the L4A vehicle with E25, E27.5 and E30.

L5B - Engine Rotation Speed (RPM) x Time

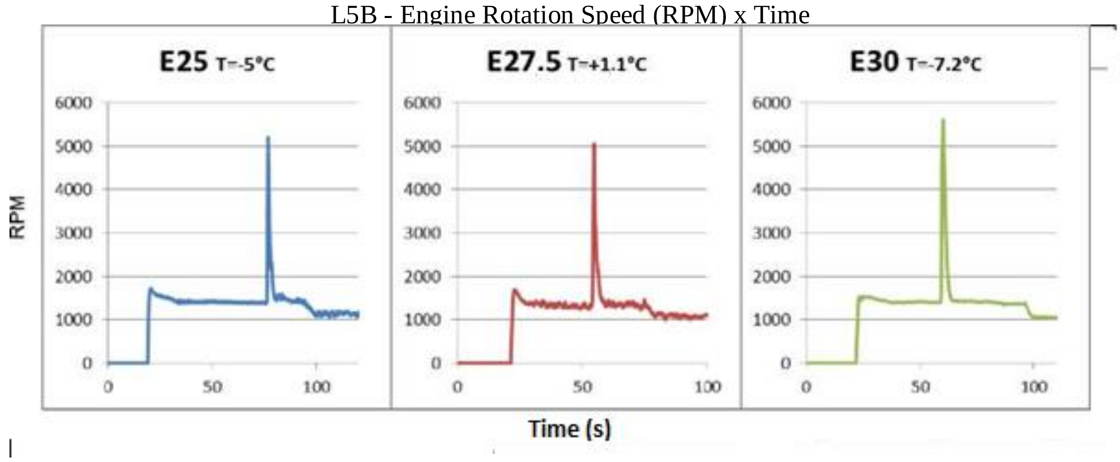


Figure 25 - Chart showing the engine rotation speed x time of the L5B vehicle with E25, E27.5 and E30.

The above engine rotation profiles show that it was possible to perform the start, idle speed and free acceleration steps with the three test fuels in all vehicles, except for the L2B vehicle using E30, which was unable to perform the free acceleration step.

Variations in engine rotation speed observed during the idling periods of the L2A, L2B, L3B, L4A and L5B vehicles with E27.5 represent measurement noise, since the driver did not note any occurrences with a compatible behavior during the tests. Therefore, such variations were not considered as malfunctions.

Table XIV below provides a summary of the test driver's comments for the cold start and cold engine drivability tests.

Table XIV: Summarized comments of the driver that took part in the starting and cold drivability tests.

PROCONVE PHASE	L2		L3		L4	L5		L6
VEHICLE	L2A	L2B	L3A	L3B	L4A	L5A	L5B	L6B
TECHNOLOGY	ELECTRONIC CARBURETOR	SINGLE-POINT INJECTION	MULTI-POINT INJECTION	MULTIPOINT INJECTION	MULTI-POINT INJECTION	MULTI-POINT INJECTION	MULTI-POINT INJECTION	INDIRECT INJECTION
FUEL	**E25**							
ATTEMPTS	1	1	1	1	1	1	1	1
START-UP								
IDLE SPEED								
FREE ACCELERATION								
DRIVABILITY								
FUEL	**E27.5**							
ATTEMPTS	1	1	1	1	l	1	1	i
START-UP								
IDLE SPEED								
FREE ACCELERATION								
DRIVABILITY								
FUEL	**E30**							
ATTEMPTS	1	1	1	1	i	1	1	1
START-UP								
IDLE SPEED								
FREE ACCELERATION								
DRIVABILITY								

NORMAL MINOR FAULT MODERATE FAULT MAJOR FAULT

Based on the results shown, it can be observed that the L2A and L2B vehicles, with older technology, manufactured at the time of the PROCONVE L2 phase and equipped with electronic carburetor and single-point electronic injection, had minor and moderate faults in them in some steps of the start-up and cold start and cold engine drivability test with the three test fuels. Only the L2B vehicle using E30 had a major fault in it, not being able to complete the free acceleration step. The repetition of this test was carried out, and the free acceleration step was completed with the occurrence of a moderate fault. It should be noted that even when the E25 fuel was used, there were low-temperature faults in the above-mentioned vehicles.

For vehicles manufactured from the PROCONVE L3 phase onwards, no failures were observed in any of the steps of the cold start and cold start and cold engine drivability test, all steps being carried out normally. Only the L3A vehicle showed irregular idle speed after the free acceleration step. However, this fault happened again with the three test fuels and, therefore, it was discarded as a fault that would have been caused by the fuel.

5.1.2. *Re-acceleration (Speed Recovery)*

5.1.2.1. Test methodology

The performance of the vehicles with different fuels was evaluated through speed recovery tests on a test track. The test procedure is based on the recommended practice SAE J1491:2006 (9) and consists of the measurement of the time elapsed during re-acceleration from 40 to 80 km/h, 60 to 100 km/h and 80 to 120 km/h. With respect to each one of these speed intervals, the manual transmission vehicles are tested with the antepenultimate, penultimate and last gears engaged. The automatic transmission vehicles are tested with the gear in the "D" ("Drive") position.

In this procedure, the vehicle speed is initially stabilized at the minimum value of the interval, with the corresponding gear engaged. The vehicle is then accelerated at full throttle until the maximum speed value of the interval is reached and, then, the time elapsed in this period is recorded.

For measuring the speed recovery times, the optical sensor Correvit L350 Acqua, which was installed on the side of the vehicle, was used to record distances, speeds and travel times. Figure 26 illustrates one of the test vehicles during the test on the track of CAEx (Centro de Avaliações do Exercito = Army Testing Center) in Rio de Janeiro.

Figure 26 - Test vehicle in the re-acceleration (speed recovery) test.

The result of each test is the average of the times obtained in consecutive trips to the opposite ends of the track, in order to offset possible differences related to road inclination and wind direction. All results with a difference of less than 10% between the measurements in both directions were accepted.

For each fuel tested, at least 12 tests were carried out in each speed interval and the results were considered valid when their deviation from the mean was less than 3%. The dispersion of each set of valid results is measured by the coefficient of variation, which is also limited by 3% for the final approval of the tests.

In the statistical treatment, when the influence of the fuel was found to be significant based on the Student's t-test, at a confidence level above 95% (p level < 0.05), the means were compared to each other by calculating the percentage difference (*). In cases where it was not possible to rule out the hypothesis of statistical equality between the means, the results were presented as "no diff."

5.I.2.2. Results and Discussion

Figures 27 to 33 below show a comparison of the average results of the speed recovery times obtained for the E25, E27.5 and E30 fuels of the L2B, L3A, L3B, L4A, L5A, L5B and L6B vehicles, respectively. The results of these tests are detailed in Annex IV.

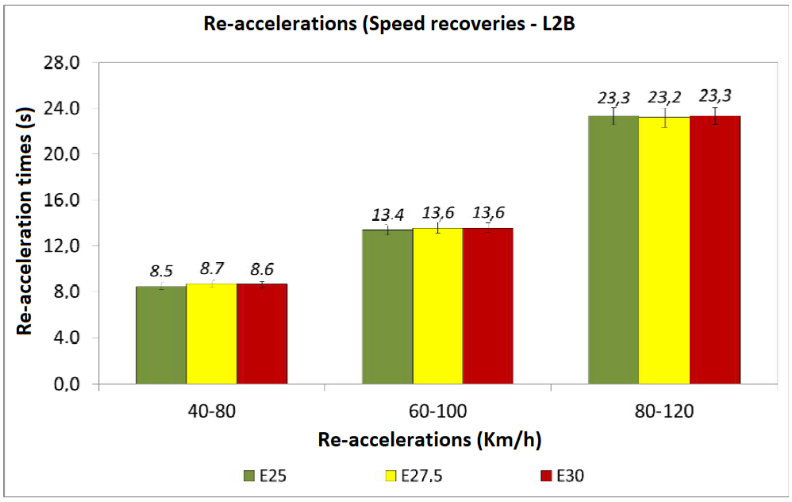


Figure 27 - Re-acceleration (Speed Recovery) times obtained with the L2B vehicle

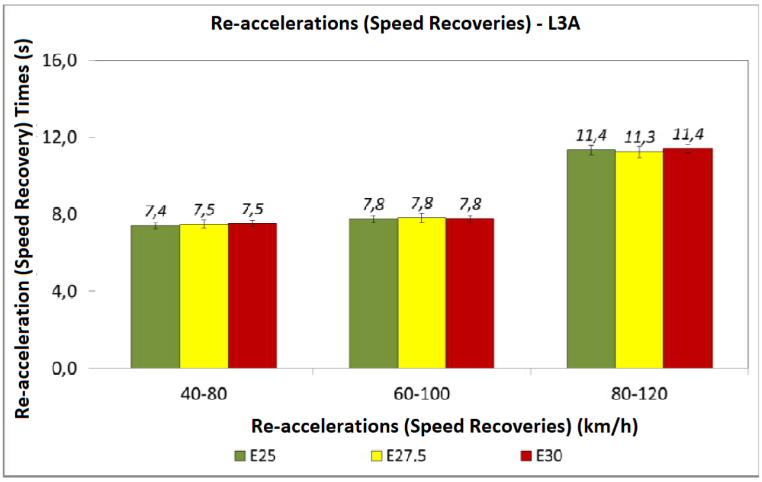


Figure 28 - Re-acceleration (speed recovery) times obtained with the L3A vehicle.

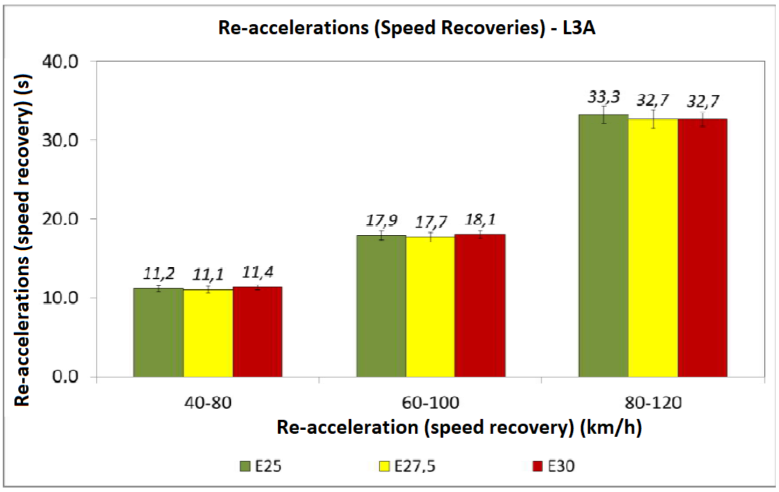


Figure 29 - Re-acceleration (speed recovery) times obtained with the L3B vehicle.

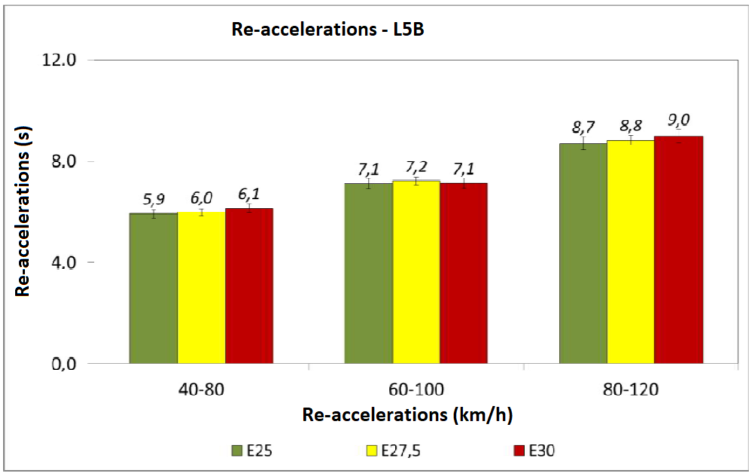


Figure 32 - Re-acceleration times obtained with the L5B vehicle.

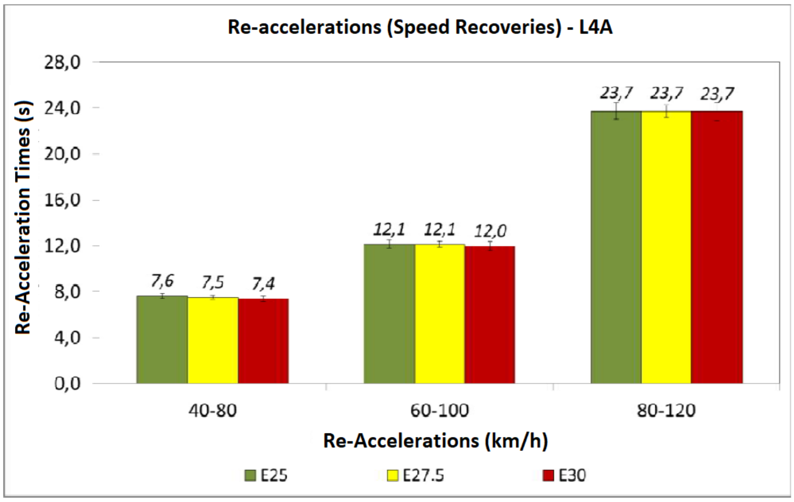


Figure 30 - Re-acceleration (speed recovery) times obtained with the L4A vehicle.

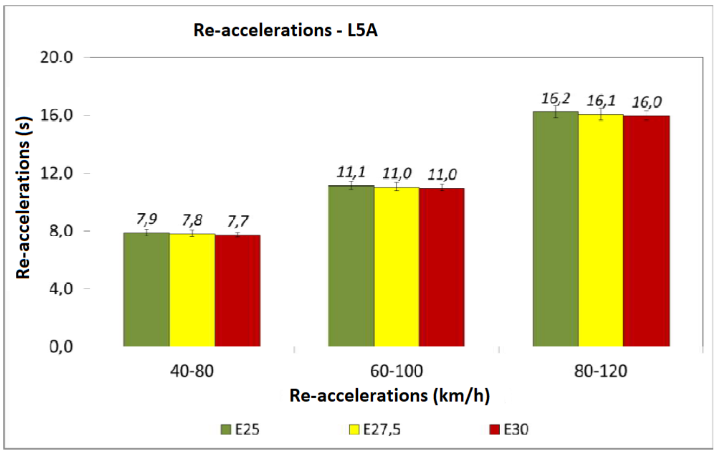


Figure 31 - Re-acceleration (speed recovery) times obtained with the L5A vehicle.

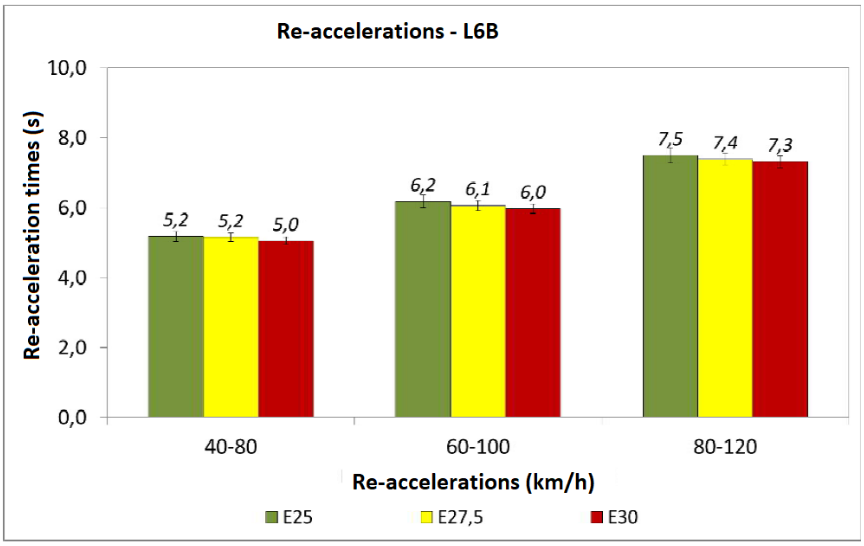


Figure 33 - Re-acceleration (speed recovery) times obtained with the L6B vehicle.

It was found that, in all cases, the differences between the speed recovery times with fuels E27.5 and E30 in relation to E25 were in the order of tenths of seconds. Tables XV and XVI show the percentage differences for E27.5 and E30, respectively, in relation to the reference fuel E25.

In these tables, the negative variations represent a reduction in the speed recovery times and, therefore, better performances (highlighted in green). Positive variations indicate worse performance (in red). In cases in which there were no statistically significant differences, the "no diff." code was used.

Table XV - Percentage differences of the speed recoveries with E27.5 in relation to E25.

Speed Recoveries - E27.5 x E25
Percentage Differences (%)

Vehicles	*40 to 80 km/h*	*60 to 100 km/h*	*80 to 120 km/h*
L2B	2.6%	no diff.	no diff.
L3A	no diff.	no diff.	no diff.
L3B	no diff.	no diff.	no diff.
L4A	-1.7%	no diff.	no diff.
L5A	no diff.	no diff.	no diff.
L5B	no diff.	1.5%	no diff.
L6B	no diff.	-1.9%	-1.4%

It was found that, in general, the vehicles tested were not very sensitive to changes in the ethanol content in the gasoline, from 25% to 27.5%, with no major differences in most of the tests. Two of the seven vehicles tested (L2B and L5B) showed marginal trends towards the worsening of performance and two others towards an improvement (L4A and L6B).

Table XVI - Percentage differences of the speed recoveries of the E30 fuel in relation to E25.

	Speed Recoveries - E27.5 x E25 Percentage Differences		
Vehicles	*40 to 80 km/h*	*60 to 100 km/h*	*80 to 120 km/h*
L2B	no diff.	1.5%	no diff.
L3A	1.7%	no diff.	no diff.
L3B	1.4%	no diff.	no diff.
L4A	-3.4%	no diff.	no diff.
L5A	-1.9%	-1.5%	-1.6%
L5B	3.6%	no diff.	3.4%
L6B	-2.6%	-3.3%	-2.3%

With regard to the use of E30, it can be observed that there were more cases of statistically significant differences, with variations of up to 3.6%. In this case, four of the seven vehicles showed trends towards worse performance, a trend that was more consistent in older vehicles (L2B, L3A and L3B). In vehicles with more up-to-date technology, there was a trend towards a slight improvement in performance, except for the L5B vehicle.

5.2. MOTORCYCLES

Just like in the case of the performance tests with vehicles, the tests with motorcycles were also done at CAEx, however, they were carried out by professionals sent by ABRACICLO, who carried out the tests according to their company's own procedures, which are used in the two-wheel segment. The full description of the tests, including the test procedures, can be found in the report issued by ABRACICLO, contained in full in Annex VI. A summary of this report is described in items 5.2.1 and 5.2.2.

5.2.1. Cold start and cold engine drivability

5.2.1.1. Test Methodology

The tests were conducted in a refrigerated container, where each test was started when the oil temperature reached 0°C. Before each test, the previous fuel was removed from the tank, feed system lines and carburetors. The motorcycles equipped with electronic injection were conditioned by reheating the engine at 80°C in a constant rotation at around 4000 rpm, to ensure recognition of the new fuel.

More information about the methodology can be found in Annex VI.

5.2.1.2. Results and Discussion

All the motorcycles, with all the fuels, did not have difficulties in the cold start, except for PM1A, which was equipped with non-original parts (carburetor and exhaust) and had functional problems at the low temperature, with the E30 fuel.

More information about the results obtained can be found in Annex VI.

5.2.2. Speed Recoveries

5.2.2.I. Test methodology

When the tests were conducted, the engine of the motorcycles was heated (to temperatures above 80°C) and, then, the speed was stabilized in the last gear, the accelerator was abruptly actuated to full throttle and the time to cover 200 meters in acceleration was recorded. The speeds established varied according to the engine capacity ("cc") of each motorcycle, as described below:

- 30 and 40 km/h for the M3A model;
- 40 and 50 km/h for the PM1A, M1A and M2A models:
- 50 and 60 km/h for the M3B model.

At least 6 runs were performed in each direction of the track for each speed mentioned. Considering that motorcycles were used, a tolerance of ± 0.4 seconds over the mean of the measurements was adopted as the criterion of approval for each fuel. Before each test, the fuel that was previously in the tank, in the feeding system lines and in the carburetors was removed. As in the cold start tests, the vehicles equipped with electronic injection were conditioned by reheating the engine at 80°C in constant rotation at around 4000 rpm, to ensure recognition of the new fuel to be tested.

More information about the methodology can be found in Annex VI.

5.2.2.2. Results and Discussion

During the tests, the evaluator did not identify the occurrence of significant faults, chokes or loss of performance for the three fuels tested, and all motorcycles were approved in the hot-start drivability condition.

The average time variation between the passes for each fuel is less than 0.4 seconds and was considered acceptable for the conditions of use of motorcycles and other variables such as wind, upward slope or downward slope, where we did not identify that the difference in the ethanol content had influenced the results.

In relation to the M1A motorcycle, the average time variation between the passages for each fuel showed a higher dispersion for the E27.5 fuel, but clearly caused by lateral wind gusts (reported by the evaluator). However, if the general average of the graphs was evaluated, it would be possible to conclude that the difference between the fuels was very small (less than 0.4 seconds) and considered acceptable for the conditions of use of the motorcycles.

In relation to the PM1A motorcycle, the evaluator identified the presence of small faults and chokings, but they were basically the same for the three fuels E25, E27, and E30. In the dispersion recovery charts (Annex VI) it is possible to notice a gain in the times (about 0.3 seconds) as the ethanol content increases. The probable cause may be related to the fact that the carburetor of this motorcycle is not original, and also because it is a copy of an older version of this model, equipped with a fuel injector where the air / fuel mixture can be richer with E25% and more adequate (poor) with E30%, showing improvement in the results.

The complete results of these tests are detailed in Annex VI.

6. TYPICAL CURVES IN THE ENGINE TEST BENCH

The reason for conducting engine power curve tests lies in the comparison of the different fuels under controlled test bench conditions, thus reducing the number of influence variables and the variability of the results. We decided to select an engine that would represent the trend towards the new direct injection technologies in engines of the Otto cycle. These new technologies meet the increasingly stringent requirements for reducing emissions of pollutants and increasing energy efficiency, in line with the new challenges of the INOVAR AUTO program.

6.1. Test methodology

We used a commercial 'spark ignition' and 'direct gasoline injection' engine with turbocharger and *intercooler* that equips some models of vehicles in the domestic market. The engine has four cylinders in line and has been adapted to work on a dedicated basis with domestic gasoline. It was installed in a test bench of the Engine Laboratory of CENPES (figure 34) equipped with a dynamometer of the Borgui & Saveri brand, model FE 300-S, of the eddy current type , with maximum power, torque and rotation of 220 kW, 610 Nm and 12000 rpm, respectively. The fuel mass flow meter is of the AVL brand, model 735S, based on the Coriolis principle, and operates in conjunction with an AVL fuel temperature controller, model 753C.

Figure 34 - Engine installed in CENPES's test bench.

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The test bench has an AVL *Puma Open* automation system for operation control and recording the 'engine' and 'test room' variables of interest. The engine operated under controlled conditions, in such a way that the temperature and humidity of the intake air before the engine compressor were maintained at 25 ± 2°C and 50%, the engine cooling water was controlled at 92 ± 2°C, the temperature of the lubricating oil was limited to 100°C and the fuel was controlled at 20°C.

A wideband lambda sensor was fitted to the exhaust, before the engine catalytic converter, to monitor the air-fuel mixture conditions during the tests using the MoTeC Professional Lambda Meter (PLM).

Two engine operating situations were selected: full load and partial load, including power ratings, energy efficiency (specific fuel consumption, defined as the ratio between hourly mass consumption and engine power) and exhaust temperature before the catalytic converter. The power curves were calculated at full load and at 50% load, that is, 50% of the full load torque at each speed of rotation of the engine selected. The torque values corresponding to the curves with 50% load were previously calculated with the reference fuel (E25) and kept constant in the tests with the three fuels (E25, E27.5 and E30). The tests were performed in accordance with the ISO 1585 ABNT NBR Standard ([10]).

For the statistical treatment of the data, three power curves were made at full load and three curves with 50% load for each product. The averages of the results of the variables of interest with the different fuels were compared statistically with the ANOVA technique, using a confidence level of 95%. Based on the history of the laboratory tests, it is estimated that there will be a maximum measurement uncertainty of 1.0% in the results of the variables of interest.

Before the start of the power curve sequence, a heating cycle was performed until the engine oil and water temperatures reached the operating regime values. In each operating condition, the engine was operated for one minute for stabilization, followed by another minute for recording of the variables of interest. Power, specific consumption and exhaust temperature were recorded, and these variables were used to compare the results of the different fuels. The power was corrected for a reference condition (25°C and 99 kPa ambient pressure) according to the ISO 1585 ABNT Standard. In addition to the variables used for comparison of the results, others were recorded, related to the control, monitoring of the

engine and test bench. Among them, it is possible to list the ambient pressure and temperature, the temperature, humidity and pressure of the intake air, cooling water and engine oil temperatures.

6.2. Results and Discussion

This section shows the results of the corrected power, specific consumption and exhaust temperature of the engine at full load, using the E25, E27.5 and E30 fuels. The results of the specific consumption of fuels E25, E27.5 and E30 at partial load are also shown.

The results for the corrected power curves are shown in Figures 35 and 36, comparing, respectively, the performance of the E27.5 fuel with the reference E25 and the performance of E30 with E25.

Overall, the results did not show statistically significant differences of power between the E27.5 / E30 fuels and E25. The maximum differences were -2.3 and -1.6%, respectively, only found in the revolutions up to 2500 rpm.

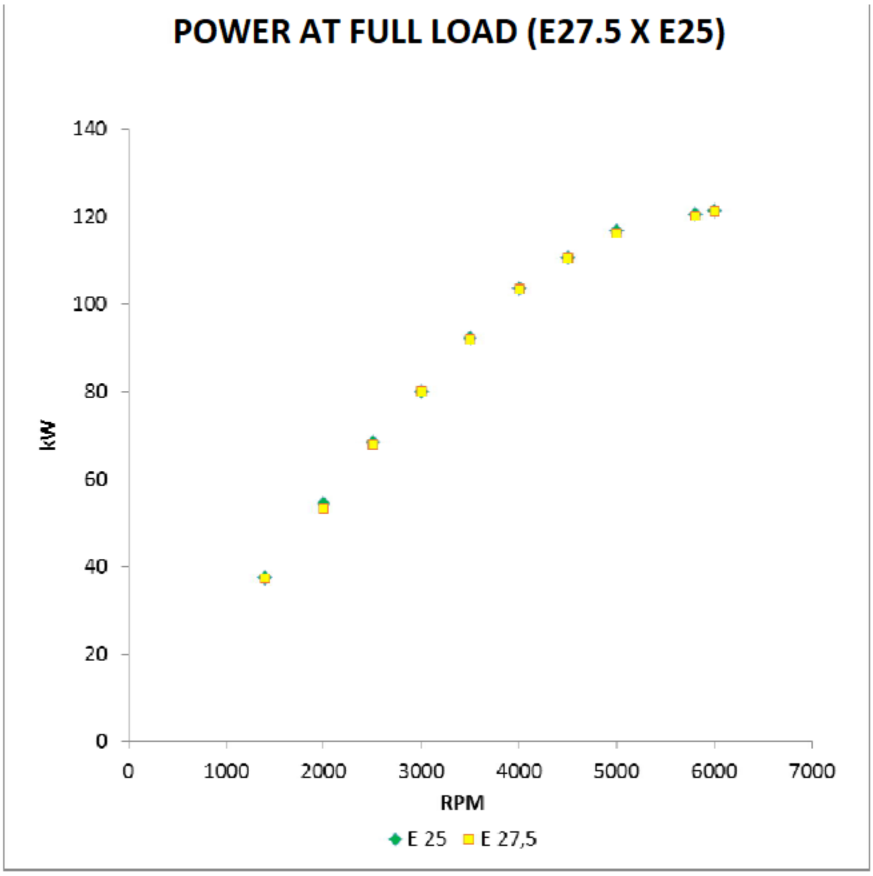

Figure 35 - Power at full load (E27.5 x E25)

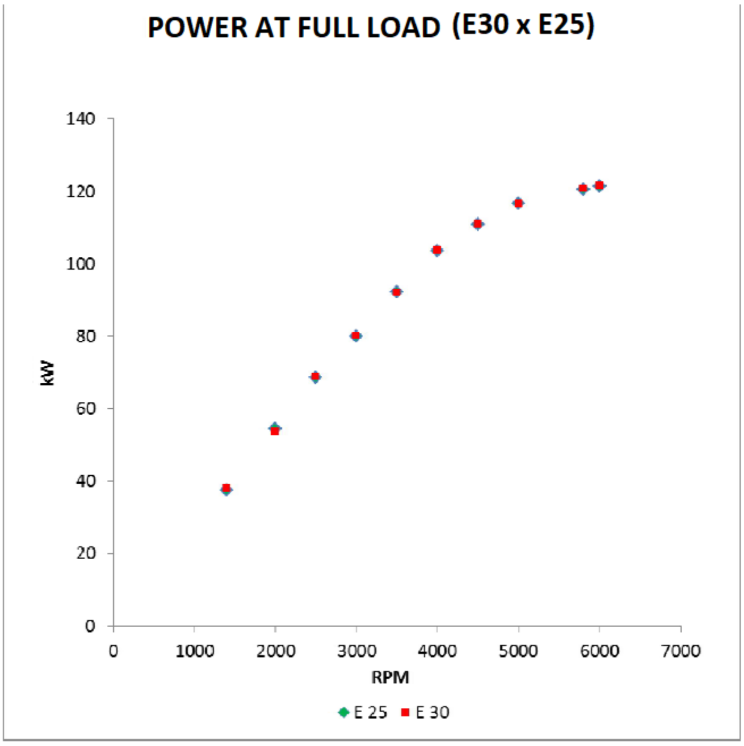

Figure 35 - Power at full load (E30 x E25)

The results for the specific fuel consumption at full load and at partial load are presented in figures 37 to 40, comparing, respectively, the performance of the
E27.5 fuel with the E25 reference and E30 with E25.

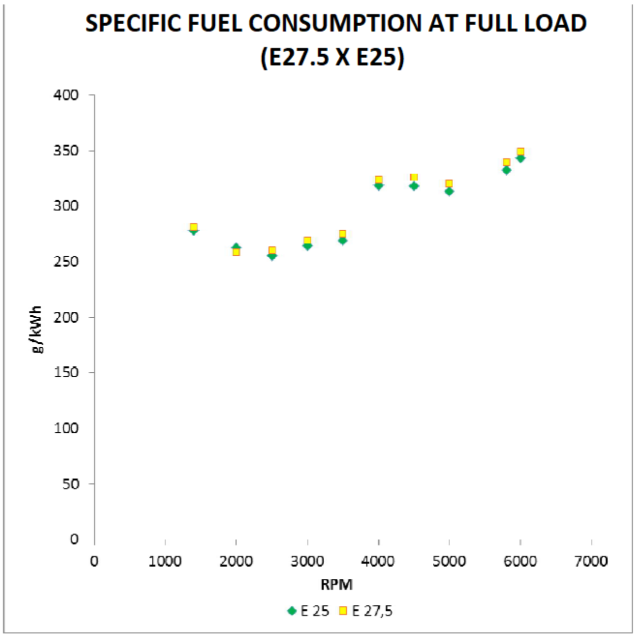

Figure 37 - Specific consumption at full load (E27.5 x E25)

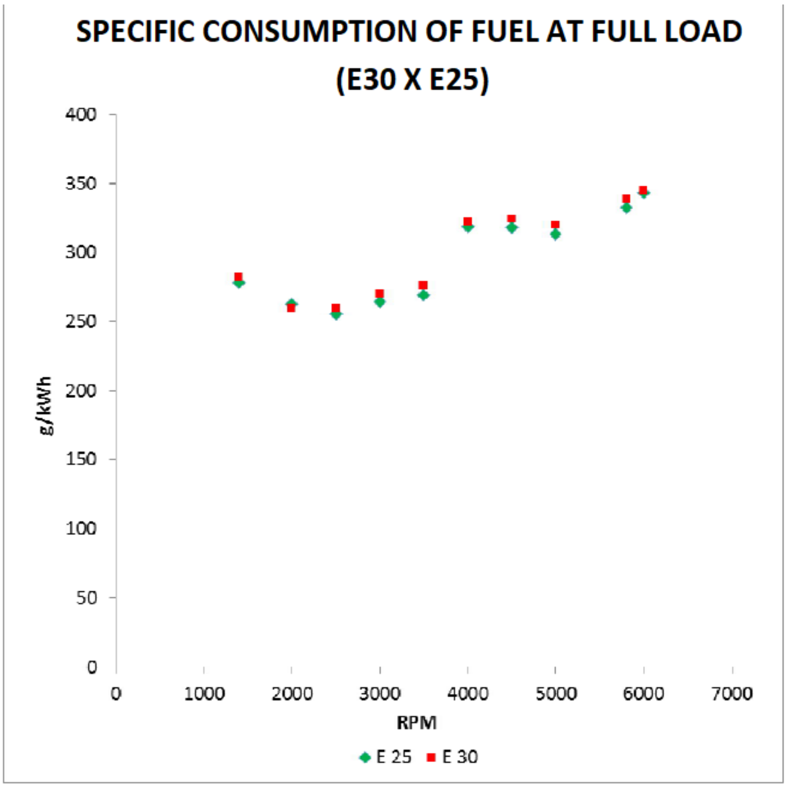

Figure 38 - Specific consumption at full load (E30 X E25)

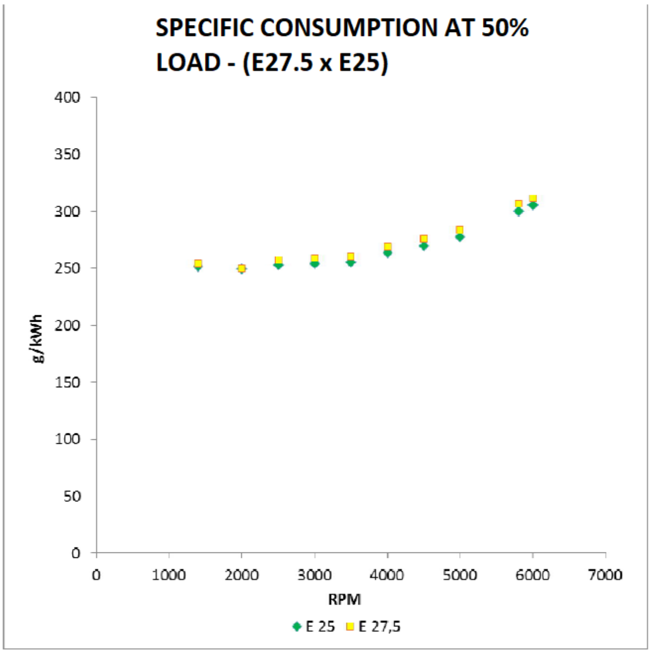

Figure 39 - Specific consumption at partial load (E27.5 x E25)

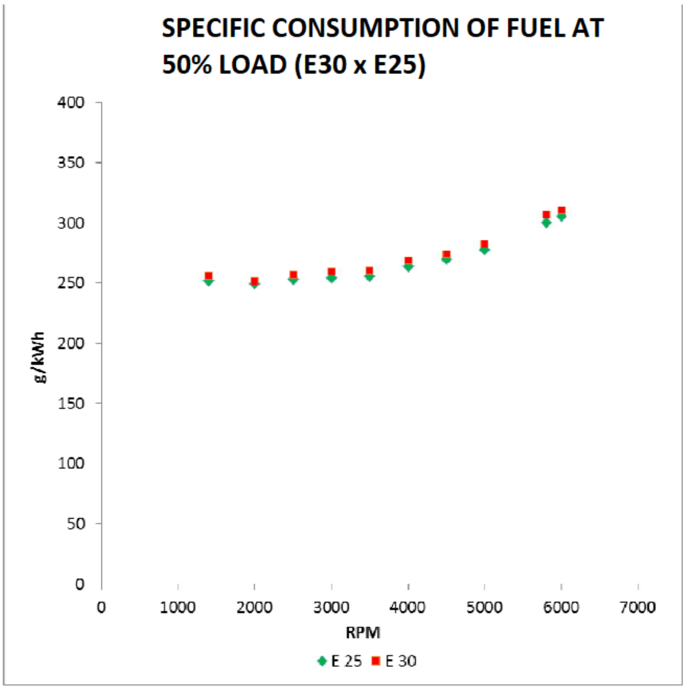

Figure 40 - Specific consumption at partial load (E30 x E25)

The specific consumption, both at full load and at partial load, showed an increase of up to 2.5% of the E27.5 and E30 fuels in relation to E25, mainly due to the reduction in the calorific value of the blend with the addition of higher ethanol contents.

With respect to the exhaust temperature, the most critical condition is the full load. The results were measured before the catalytic converter and are shown in Figures 41 and 42. The performance of the E27.5 fuel is compared with the reference E25 and the performance of E30 is also compared with E25.

Overall, the difference between the exhaust temperature at full load of the E27.5 / E30 fuels and E25 was not statistically significant. The maximum variations found were in the order of 1.0%, within the measurement uncertainty of the dynamometer test bench.

The results obtained in the typical performance curves collected in the test bench can be found in Annex V to this report.

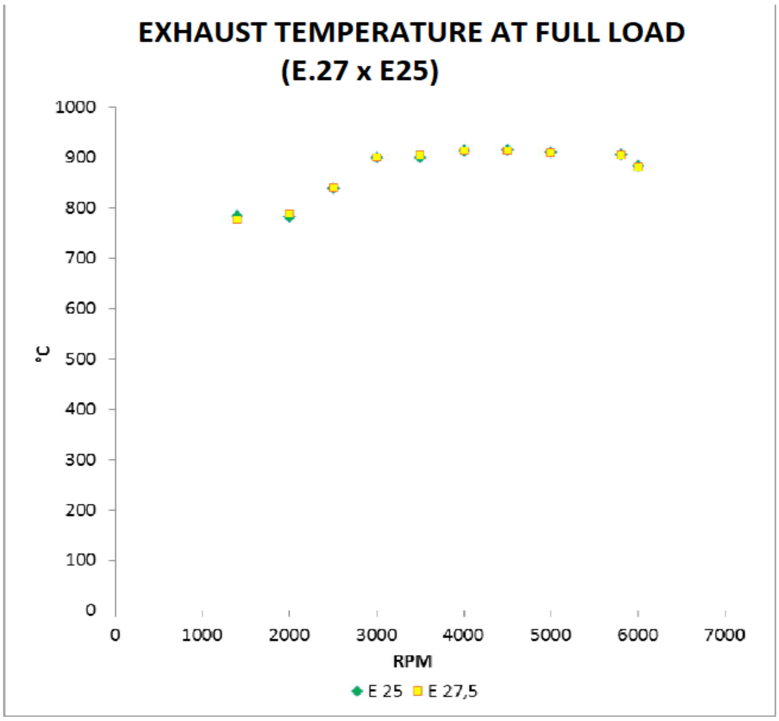

Figure 41 - Exhaust temperature at full load (E27.5 x E25)

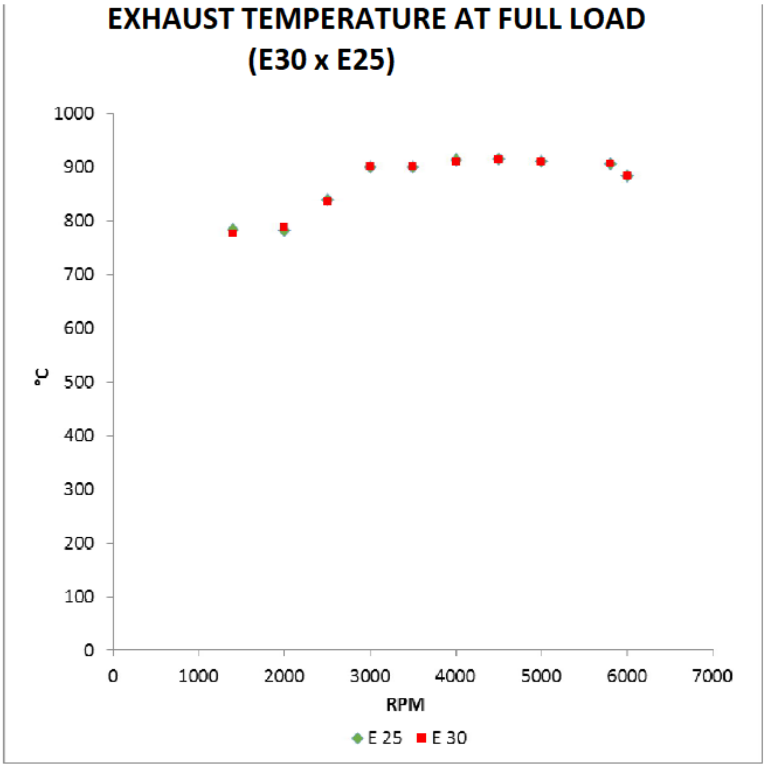

Figure 42 - Exhaust temperature at full load (E30 x E25)

7. EVALUATION OF PHYSICAL-CHEMICAL PROPERTIES

The presence of ethanol in the gasoline causes changes to its physicochemical properties, which can affect the performance of the engines. The main advantages associated with the use of ethanol are greater resistance to detonation and lower levels of CO2 emissions. However, some possible disadvantages, such as increased consumption, cold starting difficulty, increased formation of gum and volatility, should also be considered. The following is an evaluation of some of these effects on the physicochemical properties of gasoline/ethanol blends, for proportions of 25, 27.5 and 30% anhydrous ethanol in the blend.

7.1. Fuel Characterization

To assess the physical-chemical properties of gasoline C with different levels of anhydrous ethanol, gasoline from two different refineries was selected. The characterization of these fuels according to resolution ANP 40/1013 is shown in Table XVII.

Table XVII - Results of the Characterization of Gasolines S50 (Gasoline A)

Properties	Methods Used	Results	
		SAMPLE A 2014-013098-50	SAMPLE B 2014-014049-26
Appearance	- Visual	LII	LII
Color	- Visual	light yellow	slightly yellow
Corrosivity to copper	ASTM D130	1 a	1 a
Distilled: PIE, C 10% evaporated °C 50% evaporated °C 90% evaporated °C PFE, °C Residue, % v	ASTM D86 (automatic)	 33.6 54.0 101.9 167.4 206.2 1.0	 31.7 53.4 95.1 162.4 204.7 1.0
Sulfur content, mg/kg	ASTM D5453	32	50
Current washed gum, mg/100 mL	ASTM D381	1.0	< 0.5
Specific density at 20°C, kg/m^3	ASTM D4052	739.6	731.3
Vapor pressure at 37.8°C, kPa	ASTM D5191	58.5	48.0
Types of Hydrocarbons: Aromatic, % vol. Olefinic, % vol. Saturated, % vol. Not identified, % vol.	CG	29.2 18.4 52.1 0.3	22.0 25.3 52.2 0.5
Benzene, % vol.	CG	1.05	0.79

LII - clear and free of impurities

7.2. Volatility Assessment

The parameter that best defines the volatility of a fuel is the vapor pressure. In general, the presence of ethanol in gasoline, in proportions of up to 20%, increases the vapor pressure, resulting in an increase in the volatility of gasoline C, and consequent increase in evaporative losses. At higher ethanol concentrations, the vapor pressure tends to decrease ([11]). The vapor pressure results in the evaluated blends are shown in Table XVIII.

Table XVIII - Evaluation of the vapor pressure of gasolines with different ethanol contents.

Vapor pressure, KPa	**Results (ASTM D5191)**		
	E25	**E27.5**	**E30**
Sample A	63,4	62,9	62,5
Sample B	53,1	52,7	52,4

Although, numerically, there is a towards a decrease in vapor pressure in this range, all results obtained for samples A and B with 25, 27.5 and 30% of anhydrous ethanol fuel are within the uncertainty of the experimental method[1]. Therefore, the increase of the anhydrous ethanol content from 25 to 30% has little influence on the vapor pressure of gasoline C.

7.3. Lubricity Assessment

The concept of lubricity may be defined as the ability of a fluid to prevent friction and wear between metal surfaces in relative motion by promoting lubrication. The higher the fluid lubricity, the lower the friction generated and, consequently, the lower the measured wear.

At the technical meetings held with MME, ANFAVEA expressed concern about the effect of increasing the content of anhydrous ethanol on the lubricity of gasoline C. Although it is not a gasoline specification property, the recent concern with gasoline lubricity arises from the introduction of direct injection engines in the Brazilian market that, when working with pressures higher than the traditional injection systems (PFI), become more susceptible to problems related to lubricity.

There is no standardized method for assessing the lubricity of gasoline. In general, we use the diesel oil method (ASTM D6079) of the HFRR - *High Frequency Reciprocating Rig Method* adapted for gasoline by modifying the test vessel to prevent excessive evaporative losses.

The results of lubricity in the evaluated blends are presented in table XIX.

Table XIX - Evaluation of the lubricity of gasolines with different ethanol contents.

Lubricity,	**Results (ASTM D6079)**		
	E25	**E27.5**	**E30**
Sample A	696	684	670
Sample B	706	694	684

Although, numerically, there is a trend towards improved lubricity (decrease in the groove) in this range, all results obtained for samples A and B with 25, 27.5 and 30% of anhydrous ethanol fuel are within the uncertainty of the experimental method. Therefore, the increase of the anhydrous ethanol content from 25 to 30% in the gasoline has little influence on the lubricity of gasoline C.

7.4. Oxidation Stability

The degradation of the gasoline over time is a natural phenomenon caused by oxidation. This phenomenon is accelerated by the presence of oxygen, light and increased temperature. The speed at which it occurs also varies according to the gasoline chemical composition. The oxidation of gasoline is characterized mainly by the formation of gum. This residue can affect vehicle drivability, reduce engine performance and increase emissions of pollutants into the environment.

In general, the presence of ethanol in gasoline contributes to the degradation of the product due to the acceleration of the oxidation process. Studies with gasoline / ethanol blends containing 25% ethanol (14) indicated that the addition of alcohol to gasoline reduces the stability of gasoline C, contributing to the increase in the formation of gum during storage.

For the evaluation of the stability to the oxidation of the gasoline, accelerated tests can be carried out. Of the different tests used, the most reliable to predict gasoline stability is the aging test at 43°C for 4, 8 or more weeks. Much of the work published in the technical literature affirms that this test reproduces, with a good level of confidence and faster, the oxidation process at room temperature ([15]).

2 - The repeatability of the ASTM D6079 ([13]) method is equal to 50 um. For samples of diesel oil that use a modified method, this uncertainty is even higher. The values were compared by the repeatability of the method, since all the results were obtained on the same day, by the same technician, under the same operating conditions.

To evaluate the influence of the ethanol content on the gum formation, the samples evaluated were aged at 43°C, using an adaptation of the ASTM D4625 method ([16]), which minimizes the evaporation of the fuel. The gum content was then evaluated at the end of 4 and 8 weeks of storage for samples A and B. The results of the aging test in the blends evaluated are shown in Table XX. For these tests, all blends were made in duplicate.

Table XX - Aging tests at 43 ^{0}C (ASTM D4625) for gasolines with different ethanol contents.

Current washed gum, mg/100 mL	**Results (ASTM D381)**					
	E25		**E27.5**		**E30**	
Sample A (start)	< 0.5		< 0.5		< 0.5	
Sample A, 4 weeks	< 0.5	< 0.5	1.0	2.0	< 0.5	< 0.5
Sample A, 8 weeks	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
Sample B (beginning)	1,5		0,5		1,5	
Sample B, 4 weeks	2,5	2,0	2,0	2,0	< 0.5	< 0.5
Sample B, 8 weeks	2,5	3,0	3,0	2,0	2,5	2,5

Despite the numerical variability of the gum values during the aging tests, all results for the same storage time of each sample with 25, 27.5 and 30% ethanol are within the uncertainty of the experimental method. Therefore, the increase in the anhydrous ethanol content in gasoline from 25 to 30% has little influence on the stability to the oxidation of gasoline C.

3 – The reproducibility of the ASTM D381 (17) method is equal to 2.0 mg/100 ml for current gum values of 0.5 mg/100 Ml. In this case, since the tests were not carried out on the same day, we used the reproducibility of the method to compare the results.

8. CONCLUSIONS

In this study, the impact of different ethanol contents added to gasoline was evaluated. In this conclusion, emphasis was given to the evaluation of the results achieved with E27.5. For better understanding, these conclusions will be issued in different groups of the segment involved.

8.1. Vehicles:

With the increase in ethanol content between the levels of 22 and 30% v/v, considering the sample of 8 vehicles tested, there was a general trend towards the maintenance or reduction in the emissions of hydrocarbon (THC and NMHC), CO and CO_2. The NOx emission of the older vehicles (L2 and L3) also followed this trend, but for the newer ones (L4 vehicles and beyond) there was an increase in one vehicle, while for the others there was no statistically significant difference. In the case where there was a rise in NOx, the highest value that was found was 45% below the respective PROCONVE limit. For aldehydes, there was an increase in emission in 3 vehicles. For them, the highest emission found was 95% below the PROCONVE limit. With respect to fuel economy (in the "city" and on the "highway"), there was a trend towards reduction in all vehicles.

Specifically, with respect to the comparison between the results achieved with E27.5 and E25, statistically significant changes were found only for CO (reduction of up to 11% in 2 vehicles) and fuel economy (reduction of 1% in other 2 vehicles).

With respect to the drivability and cold start tests, the test vehicles with older technology, manufactured at the time of the PROCONVE L2 phase and equipped with an electronic carburetor and electronic single-point injection, had faults in them with the three test fuels. Considering the severe test conditions (0°C), extensive mileage and time of use of the vehicles, such failures did not represent restrictions on the application of E27.5. For vehicles manufactured from the PROCONVE L3 phase onwards, there were no faults in any of the steps of the cold start and cold engine drivability test, and all the steps were completed without any issues.

With respect to the speed recovery tests, in the sample that was tested, it was found that the increase in ethanol content from 25% to 27.5% in gasoline C resulted in variations in the order of approximately 2%.

8.2. Motorcycles:

Like in the case of the vehicles, for the five motorcycles tested, there was a general trend towards the reduction in THC and CO emissions, and this accompanied the increase in ethanol content between the levels of 22% v/v and 30% v/v. For CO2 emissions and for fuel economy, there was no definite trend. For NOx emissions, however, there was a trend towards the maintenance or increase thereof. in the case in which there was the elevation of this pollutant, the highest value found was 42% below its respective PROCONVE limit.

In the comparison between the results obtained with E27.5 and E25, there were reductions of up to 7% in THC, 18% in CO and 1% in fuel economy, in addition to an increase in NOx (13%) and CO2 (3%).

In the tests of cold-start drivability and speed recovery tests, carried out by ABRACICLO, the use of E27.5 was considered feasible.

8.3. Engine Performance Curves

Overall, there were no statistically significant performance differences between the results of effective power at full load between E27.5 and E25, except in the conditions up to 2500 rpm, with reduction of 0.8% to 2.3%. Specific consumption for both the full load condition and the partial load condition increased by up to 2.5%. With respect to the exhaust temperature, which is more critical at full load, these differences varied by up to 1% of the values obtained for E25, which is within the experiment's measurement uncertainty.

8.4. Physical and Chemical Properties

With regard to the physicochemical properties evaluated, it was observed that all results were within the uncertainty of the experimental methods used. Therefore, the increase in the anhydrous ethanol content in gasoline from 25 to 27.5% has little influence on vapor pressure, lubricity and stability to oxidation of gasoline C.

In conclusion, it should be emphasized that the possible effects of the new ethanol contents on the durability of components are not part of the scope of this study. This shall be part of another study that should be carried out by the automobile industry and by the segment for two-wheeled motor vehicles, represented, respectively, by ANFAVEA and ABRACICLO.

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(2) ANP (BRAZILIAN AGENCY OF PETROLEUM, NATURAL GAS AND BIOFUELS), Resolution ANP number 5/2005, of February 2005 [AGÉNCIA NACIONAL DO PETRÓLEO, GÁS NATURAL E BIOCOMBUSTÍVEIS (ANP), Resolução ANP n°5/2005, fevereiro de 2005];

(3) ANP (BRAZILIAN AGENCY OF PETROLEUM, NATURAL GAS AND BIOFUELS), Resolution ANP number 6/2005, of February 2005 [AGÉNCIA NACIONAL DO PETRÓLEO, GÁS NATURAL E BIOCOMBUSTÍVEIS (ANP), Resolução ANP n°6/2005, fevereiro de 2005];

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ANNEX I

MME LETTER number 065/2014

PETROBRAS

48380.000858/2014-00

MME (Ministry of Mines and Energy)
SPG (Secretariat of Petroleum, Natural Gas and Renewable Fuels)
Esplauada clos Ministérios, Bloco "U", 9º andar, sala 952
70065-900 - Brasilia - DF
Phone (61) 2032-5029 / spg@mme.gov.br

Letter number 065/2014-SPG-MME

Brasilia, June 2, 2014.

To Mr.
Antonio Augusto Almeida Faria
Chief of Staff of Petróleo Brasileiro SA
Address: Av. República do Chile, 65 - 23c andar 20031-912 Rro de Janeiro - RJ

Subject: Evaluation of the use of contents of anhydrous ethanol higher than 25% in the gasoline

Mr. Chief of Staff.

1. The Ministry of Mines and Energy, with the support of Petrobras / CENPES, is responsible for coordinating the studies to evaluate the technical feasibility of the addition of up to 27.5% of anhydrous ethanol to gasoline. The studies will comprise the performance of specific tests to monitor the performance of the vehicles, the consumption of fuels and the level of emissions.

2. The first step of the study will be the preparation of the terms of reference, which will be used as basis for defining the scope of the studies and the results to be achieved.

3. With this regard, I request the appointment of technical representatives from Petróleo Brasileiro SA and from CENPES Research and Development Center to join the Group that will carry out the study.

4. The first meeting will be held in Brasilia, on June 5, 2014, at the Ministry of Mines and Energy, at 08:00 p.m., in room 952, for which we take the opportunity to invite the representatives to be appointed by Petrobras.

Best regards,

MARCO ANTONIO MARTES S .ALMEIDA
Secretary of Petroleum, Natural Gas and Renewable Fuels

ANNEX II

PHYSICAL-CHEMICAL ANALYSIS OF FUELS

Results of the characterization of standard gasoline - Emission and Fuel-Economy Tests

Properties	Methods Used	Results				
		Gasoline A C 057/14 2014-012310-53	Gasoline E22 C 061/14 2014-013406-93	Gasoline E25 C 062/14 2014-013427-18	Gasoline E27.5 C 063/14 2014-013476-04	Gasoline E30 C 064/14 2014-013562-63
Appearance	- Visual	LII	LII	LII	LII	LII
Color	- Visual	light yellow	orange	orange	orange	orange
Ethanol content	NBR 13992	-	22	24	26.5	30
Corrosivity to copper	ASTM D130	1 a	1 a	1 a	1 a	1 a
Distillation: PIE, C 10% evaporated, °C 50% evaporated, °C 90% evaporated, °C PFE, °C Residue,%v	ASTM D86 (automatic)	33.2 55.4 101.1 168.2 199.1 0.6	35.4 53.9 72.5 161.2 194.8 1.2	34.7 53.1 72.6 158.5 195.0 1.1	36.0 53.3 72.8 156.3 194.3 1.1	37.1 55.2 73.6 155.4 194.4 1.1
Sulfur, mg/kg	ASTM	17	15	14	14	14
Current washed gum, mg/100 mL	ASTM D381	1.5	1.5	1.0	1.5	2.5
Specific density at 20°C, kg/m³	ASTM	731.4	744.8	745.1	749.8	750.1
Induction Period. Minutes	ASTM D525	> 720	> 720	> 720	> 720	> 720
Vapor pressure at 37.8°C, kPa	ASTM	54.8	56.5	58.2	56.7	56.2
Types of Hydrocarbons: Aromatic,% vol Olefinic. % vol. Saturated.%v Not identified, % v	CG N 2377	27.7 9.4 62.3 0.6	ND	ND	ND	ND
Benzene,%v	CG	0.18	ND	ND	ND	ND
C, % m	ASTM 5291	86.3	78.2	77.1	75.6	75.0
H, % m	ASTM 5291	13.7	13.5	13.5	13.5	13.6
O, % m	ASTM 5622	-	8.3	9.4	10.9	11.4
Gross calorific power, MJ/Kg	ASTM	46.539	42.392	41.903	41.658	40.729
Lubricity	ASTM	764	691	681	671	679

LII = Clear and free of impurities

Results of the characterization of commercial gasoline S50 - Performance tests

Properties	Methods Used	Gasoline A (C066/2014) 2014-014049-26	Gasoline E22 (C 071/2014) 2014-015433-73	Gasoline E 25 (C068/2014) 2014-015159-14	Gasoline E27.5 (C070/2014) 2014-015171-00	Gasoline E30 (C072/2014) 2014-015437-05
Appearance	**- Visual**	**LII**	**LII**	**LII**	**LII**	**LII**
Color	**- Visual**	**slightly yellow**	**orange**	**orange**	**orange**	**orange**
Ethanol content	**NBR 13992**	**-**	**22**	**24**	**27.5**	**30**
Corrosivity to copper	**ASTM D130**	**1 a**	**1 a**	**1 a**	**1 a**	**1 a**
Distillation: PIE, C 10% evaporated, °C 50% evaporated, °C 90% evaporated, °C PFE, °C Residue, %v	**ASTM D86 (automatic)**	**31.7 53.4 95.1 162.4 204.7 1.0**	**36.6 53.7 70.9 157.4 201.5 1.1**	**35.8 54.8 71.7 158.7 199.8 1.1**	**36.2 54.8 71.9 154.7 199.8 1.2**	**36.4 55.1 72.1 153.2 198.2 1.1**
Sulfur, mg/kg	**ASTM**	**50**	**37**	**36**	**35**	**34**
Current washed gum, mg/100 mL	**ASTM D381**	**< 0.5**	**0.5**	**1.0**	**1.5**	**1.0**
Induction period	**ASTM D525**	**-**	**> 720**	**> 720**	**> 720**	**> 720**
Specific density at 20°C, kg/m³	**ASTM**	**731.3**	**746.0**	**746.9**	**750.4**	**751.0**
Vapor pressure at 37.8°C, kPa	**ASTM**	**48**	**59.9**	**60.3**	**59.0**	**57.8**
Types of Hydrocarbons: Aromatic, % vol. Olefinic, % vol. Saturated, %v	**CG**	**22.0 25.3 52.2**	**ND**	**ND**	**ND**	**ND**
Benzene, %v	**ASTM**	**0.80**	**ND**	**ND**	**ND**	**ND**
C, % m	**ASTM 5291**	**86.3**	**78.7**	**77.4**	**76.8**	**757**
H, % m	**ASTM 5291**	**13.7**	**13.6**	**13.5**	**13.6**	**13.6**
O, % m	**ASTM 5622**	**-**	**7.7**	**9.1**	**9.6**	**10.7**
Gross calorific power, MJ/Kg	**ASTM**	**46.684**	**42.364**	**41.819**	**41.224**	**41.171**
Lubricity	**ASTM**	**681**	**705**	**685**	**691**	**675**

LII = Clear and free of impurities

Results of the characterization of anhydrous ethanol (C051/2014)

Tests	**Reference Methods**	**Limits**	**2014-010347-38**
Appearance	- Visual	LII	LII
Color	- Visual	(2)	orange
Total acidity, mg/L	NBR 9866	30 max.	14.4
Electrical conductivity, pS / m	NBR 10547	389 max.	103
Specific density at 20°C, kg/m^3	ASTM D4052	791.5 max.	789.4
Alcohol content, % density	NBR 5992	99.3 min.	99.9
Evaporation residue, mg/100 mL	NBR 8644	5 max.	2
Hydrocarbon content, % vol.	NBR 13993	3 max.	0
Sodium, mg/kg	NBR 10422	2 max.	1.4
Iron, mg/kg	NBR 11331	5 max.	< 0.1
Sulfate, mg/kg	NBR 10894	4 max.	0.14
Chloride, mg/kg	NBR 10894	1 max.	0.19

LII = Clear and free of impurities
(1) Resolution ANP number 7, of February 9, 2011.
(2) Orange after addition of specified dye

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ANNEX III

RESULTS OF EMISSIONS OF POLLUTANTS AND FUEL ECONOMY

Results of emissions and fuel economy in vehicles

Vehicle	Ethanol Content (%v/v)	THC (L2, L3), NMHC (L4, L5, L6) (g/km)	CO (g/km)	NOx (g/km)	Total Aldehydes (g/km)	CO2 (g/km)	"City" Fuel Economy (km/L)	"Highway" Fuel Economy (km/L)
L2A	22	1.516	4.103	0.899		184.467	11.11	16.88
L2A	22	1.644	4.024	0.912	0.08599	185.204	11.05	16.94
L2A	22	1.516	4.013	0.905	0.08027	186.147	11.02	16.82
L2A	25	1.549	3.635	0.915	0.11465	188.995	10.76	
L2A	25	1.545	3.841	0.911	0.11568	191.994	10.59	16.66
L2A	25	1.498	3.853	0.913	0.11312	191.403	10.63	16.46
L2A	27.5	1.395	3.287	0.896	0.08887	188.589	10.74	16.66
L2A	27.5	1.447	3.278	0.884	0.07232	189.909	10.66	16.68
L2A	27.5	1.417	3.421	0.892	0.08219	188.509	10.72	16.65
L2A	30	1.468	2.715	0.849	0.12932	188.918	10.65	16.49
L2A	30	1.496	2.763	0.866	0.12867	189.918	10.58	16.49
L2A	30	1.494	2.874	0.903	0.13143	190.811	10.53	16.42
L2B	22	0.460	6.549	0.529		173.501	11.74	16.76
L2B	22	0.478	6.216	0.561	0.01602	171.631	11.89	17.01
L2B	22	0.454	6.047	0.515	0.01556	170.408	11.99	17.24
L2B	25	0.479	5.364	0.514		174.676	11.64	16.76
L2B	25	0.443	5.814	0.51	0.0196	175.442	11.554	16.76
L2B	25	0.469	5.511	0.493	0.0206	171.626	11.821	17.003
L2B	25	0.482	5.964	0.512	0.0232	173.889	11.628	16.846
L2B	25	0.453	5.547	0.525		174.053	11.67	16.78
L2B	25	0.434	5.588	0.529		173.573	11.70	16.69
L2B	27.5	0.417	4.955	0.549	0.01870	174.131	11.61	16.76
L2B	27.5	0.424	5.445	0.513	0.01540	174.680	11.53	16.66
L2B	27.5	0.437	5.421	0.516	0.01160	173.431	11.60	16.67
L2B	30	0.416	4.778	0.500	0.01663	171.586	11.67	16.60
L2B	30	0,412	4,672	0,525	0,02324	171,256	11,71	
L2B	30	0,443	4,921	0,537	0,02563	170,956	11,69	16,68
L3A	22	0,371	2,392	0,892	0,00886	180,887	11,70	16,46
L3A	22	0,368	2,295	0,864	0,00805	177,044	11,96	16,53
L3A	22	0,358	2,366	0,887	0,00915	181,648	11,66	16,50
L3A	25	0,331	2,211	0,875		177,467	11,81	16,70
L3A	25	0,339	2,332	0,860	0,01222	178,733	11,71	16,73
L3A	25	0,350	2,301	0,864	0,01171	175,462	11,93	16,73
L3A	27.5	0,354	3,397	0,889		177,342	11,67	16,70
L3A	27.5	0,350	2,309	0,883		178,239	11,63	16,73
L3A	27.5	0,369	2,361	0,845		177,022	11,70	16,73
L3A	27.5	0,367	2,113	0,833	0,01068	174,875	11,861	16,71
L3A	27.5	0.353	2.145	0.861	0.01236	177.637	11.681	
L3A	30	0.348	1.977	0.896	0.01674	175.170	11.74	16.41
L3A	30	0.352	2.369	0.858	0.01464	175.034	11.71	16.48
L3A	30	0.360	2.371	0.884	0.01186	177.092	11.57	16.39
L3B	22	0.324	2.842	0.444	0.00699	202.292	10.47	14.86
L3B	22	0.332	3.064	0.439	0.00822	205.165	10.30	14.84
L3B	22	0.304	3.177	0.441	0.00677	205.104	10.30	14.89
L3B	25	0.292	2.821	0.447		203.566	10.29	14.77
L3B	25	0.284	2.894	0.426		202.130	10.35	14.76
L3B	25	0.307	3.047	0.456	0.00598	204.451	10.22	14.66
L3B	25	0.308	3.059	0.442	0.01013	204.686	10.21	14.79
L3B	27.5	0.282	2.668	0.440	0.00688	202.374	10.25	14.67
L3B	27.5	0.324	3.036	0.431	0.00698	203.711	10.15	14.70
L3B	27.5	0.309	2.998	0.434	0.00674	202.123	10.24	14.65
L3B	30	0.283	2.756	0.427	0.00973	200.784	10.22	14.57
L3B	30	0.272	2.889	0.413	0.01033	202.028	10.15	14.53
L3B	30	0.285	2.960	0.409	0.01053	202.229	10.14	14.55
L4A	22	0.072	0.964	0.121	0.00230	219.893	9.81	13.10
L4A	22	0.070	1.004	0.105	0.00230	221.144	9.75	13.05
L4A	22	0.066	0.921	0.108	0.00218	220.818	9.77	13.06
L4A	25	0.072	0.948	0.114	0.00206	221.261	9.94	12.91
L4A	25	0.065	0.842	0.125	0.00259	218.675	9.76	13.04
L4A	25	0.061	0.830	0.109	0.00269	220.128	9.70	12.89
L4A	27.5	0.066	0.874	0.116	0.00197	218.561	9.66	12.83
L4A	27.5	0.068	0.864	0.109	0.00262	219.907	9.60	12.90
L4A	27.5	0.062	0.785	0.110		219.021	9.65	12.90
L4A	30	0.063	0.804	0.117	0.00304	215.770	9.69	12.54
L4A	30	0.065	0.821	0.126	0.00288	217.480	9.62	12.79
L4A	30	0.065	0.843	0.115	0.00292	218.161	9.59	12.69

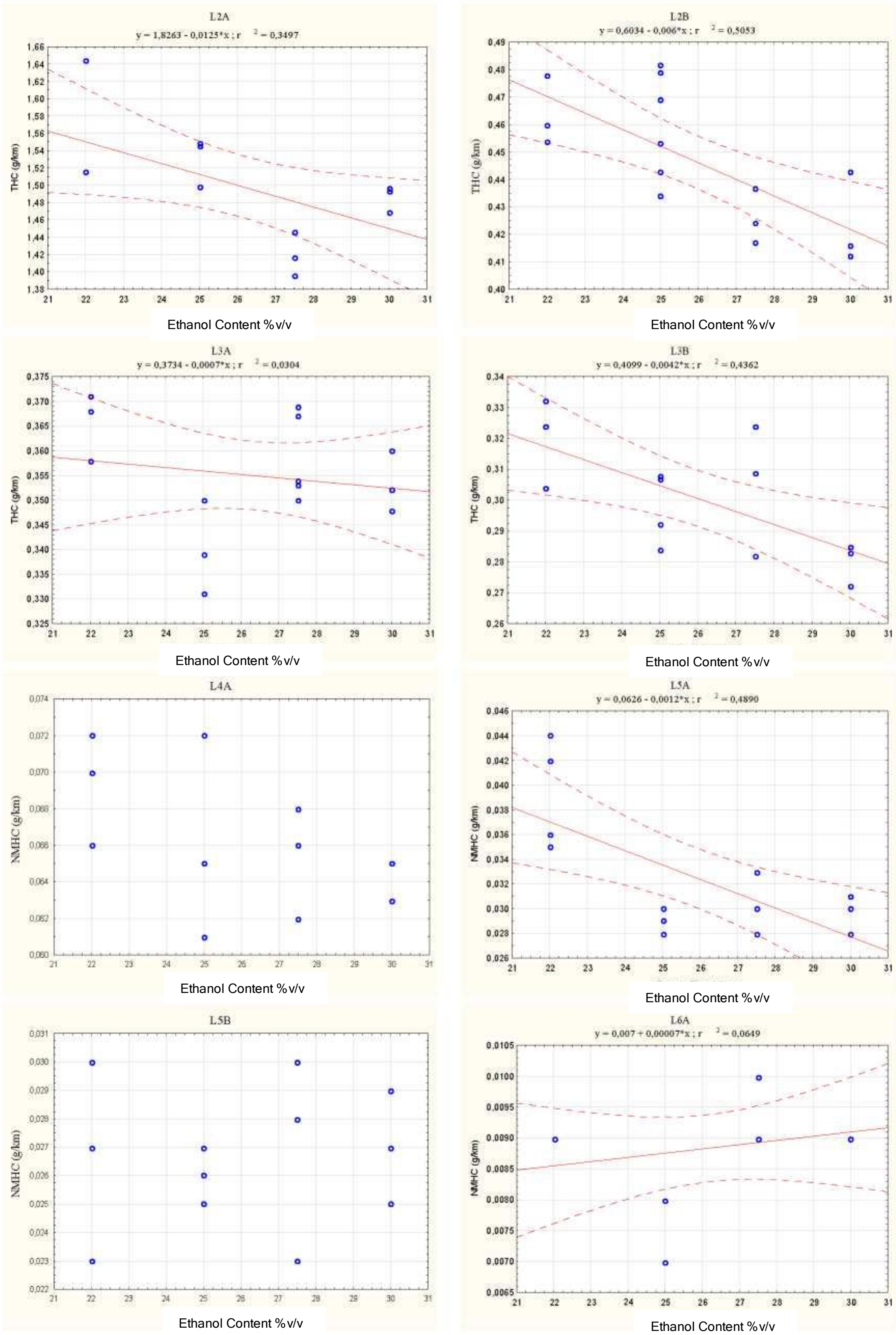
Vehicle	Ethanol Content (%v/v)	THC (L2. L3). NMHC (L4. L5. L6) (g/km)	CO (g/km)	NOx (g/km)	Total Aldehydes (g/km)	CO2 (g/km)	Urban Fuel Economy (km/L)	"Highway" Fuel Economy (km/L)
L5A	22	0.036	0.403	0.045	0.00131	167.619	12.91	17.19
L5A	22	0.042	0.383	0.059	0.00142	165.241	13.10	17.19
L5A	22	0.044	0.346	0.050	0.00143	165.508	13.08	17.13
L5A	22	0.035	0.322	0.056	0.00115	166.020	13.05	17.22
L5A	25	0.028	0.290	0.055	0.00120	163.255	13.12	17.14
L5A	25	0.030	0.299	0.063	0.00123	163.050	13.13	17.15
L5A	25	0.029	0.309	0.054	0.00124	164.145	13.04	16.76
L5A	27.5	0.030	0.325	0.054	0.00115	165.791	12.78	16.87
L5A	27.5	0.033	0.299	0.060	0.00116	166.929	12.70	16.92
L5A	27.5	0.028	0.297	0.058	0.00138	166.182	12.76	16.95
L5A	30	0.030	0.318	0.064	0.00116	167.368	12.54	16.36
L5A	30	0.028	0.267	0.060	0.00141	165.090	12.72	16.86
L5A	30	0.031	0.294	0.075	0.00174	165.853	12.65	16.66
L5B	22	0.030	0.409	0.034	0.00029	190.706	11.36	15.14
L5B	22	0.023	0.395	0.039	0.00014	189.109	11.46	15.40
L5B	22	0.027	0.439	0.050	0.00023	187.704	11.54	15.47
L5B	25	0.027	0.444	0.046		186.644	11.46	15.01
L5B	25	0.026	0.505	0.061	0.00015	189.336	11.30	
L5B	25	0.025	0.521	0.06	0.00024	187.579	11.40	15.17
L5B	25	0.025	0.487	0.054	0.00021	187.829	11.39	15.14
L5B	27.5	0.023	0.392	0.05	0.0003	190.481	11.13	14.80
L5B	27.5	0.030	0.506	0.049	0.0004	190.487	11.12	14.92
L5B	27.5	0.028	0.471	0.045		189.899	11.15	14.96
L5B	30	0.025	0.500	0.070	0.00030	186.243	11.25	14.88
L5B	30	0.027	0.474	0.057	0.00030	185.900	11.28	14.92
L5B	30	0.029	0.469	0.055		186.422	11.25	14.90
L6A	22	0.009	0.118	0.020	0.00006	205.334	10.58	14.66
L6A	22	0.009	0.123	0.022	0.00008	205.565	10.57	14.71
L6A	22	0.009	0.118	0.026	0.00007	205.568	10.57	
L6A	25	0.008	0.112	0.023	0.00010	201.651	10.65	14.68
L6A	25	0.008	0.127	0.027	0.00010	203.369	10.55	14.71
L6A	25	0.007	0.105	0.030	0.00031	203.173	10.69	14.83
L6A	27.5	0.010	0.119	0.033	0.00006	202.831	10.48	14.60
L6A	27.5	0.009	0.112	0.028	0.00010	203.217	10.46	14.57
L6A	27.5	0.010	0.109	0.035	0.00010	203.315	10.45	14.53
L6A	30	0.009	0.116	0.032	0.00012	201.631	10.43	14.68
L6A	30	0.009	0.124	0.025	0.00019	202.817	10.37	14.71
L6A	30	0.009	0.129	0.020	0.00018	201.173	10.46	14.55

Results of emissions and fuel economy in motorcycles

Motorcycle	Ethanol content (% v/v)	THC (g/km)	CO (g/km)	NOx (g/km)	CO2 (g/km)	Fuel economy (km/L)
PM1A	22	1.361	13.782	0.148	35.386	35.44
PM1A	22	1.391	13.177	0.153	34.960	36.20
PM1A	22	1.388	14.066	0.127	34.186	35.83
PM1A	25	1.262	11.925	0.161	35.089	37.16
PM1A	25	1.250	12.269	0.171	35.812	36.39
PM1A	25	1.221	12.007	0.154	35.832	36.69
PM1A	25	1.235	12.335	0.148	35.632	36.46
PM1A	27.5	1.171	10.792	0.172	36.829	37.00
PM1A	27.5	1.181	10.489	0.180	36.715	37.36
PM1A	27.5	1.191	10.494	0.178	36.566	37.43
PM1A	27.5	1.197	10.314	0.192	36.848	37.42
PM1A	30	1.040	8.934	0.204	39.158	37.28
PM1A	30	1.121	9.374	0.213	38.231	37.26
PM1A	30	1.119	9.682	0.210	38.341	36.88
M1A	22	0.828	8.426	0.113	37.778	40.54
M1A	22	0.867	8.659	0.104	36.788	40.92
M1A	22	0.825	8.494	0.116	37.485	40.68
M1A	25	0.789	7.349	0.105	36.984	42.11
M1A	25	0.772	7.589	0.100	38.754	40.45
M1A	25	0.776	7.356	0.102	37.644	41.59
M1A	27.5	0.769	7.425	0.108	38.927	40.11
M1A	27.5	0.75	7.171	0.116	38.454	40.83
M1A	27.5	0.81	7.254	0.114	37.949	40.98
M1A	30	0.779	6.566	0.107	40.846	39.27
M1A	30	0.758	6.534	0.110	40.609	39.53
M1A	30	0.762	6.665	0.108	40.561	39.40
M2A	22	0.844	6.045	0.158	43.699	38.92
M2A	22	0.791	5.418	0.163	43.297	40.03
M2A	22	0.683	6.050	0.156	43.575	39.36
M2A	25	0.774	5.466	0.184	43.784	39.19
M2A	25	0.752	5.403	0.184	44.136	39.06
M2A	25	0.697	5.643	0.174	43.933	39.06
M2A	27.5	0.812	3.607	0.214	43.286	41.28
M2A	27.5	0.811	3.387	0.222	43.822	41.14
M2A	27.5	0.850	3.819	0.218	43.003	41.15
M2A	30	0.867	3.157	0.231	43.498	41.13
M2A	30	0.897	3.340	0.230	43.405	40.89
M2A	30	0.867	3.313	0.227	43.868	40.64
M3A	22	0.242	1.400	0.086	41.211	49.22
M3A	22	0.240	1.397	0.088	41.549	48.86
M3A	22	0.248	1.385	0.082	41.401	49.02
M3A	25	0.241	1.352	0.082	41.586	48.32
M3A	25	0.237	1.340	0.082	41.171	48.81
M3A	25	0.244	1.361	0.083	41.391	48.50
M3A	27.5	0.217	1.217	0.082	41.426	48.32
M3A	27.5	0.219	1.274	0.084	41.353	48.30
M3A	27.5	0.231	1.380	0.081	41.273	48.16
M3A	30	0.234	1.179	0.088	41.205	48.08
M3A	30	0.231	1.147	0.087	41.130	48.23
M3A	30	0.233	1.180	0.087	41.418	47.85
M3A	30	0.222	1.213	0.087	41.243	48.02
M3B	22	0.208	3.613	0.067	76.591	26.22
M3B	22	0.210	3.625	0.068	76.993	26.09
M3B	22	0.205	3.756	0.067	76.876	26.06
M3B	25	0.219	3.582	0.067	77.521	25.63
M3B	25	0.218	3.269	0.069	77.933	25.65
M3B	25	0.215	3.528	0.065	77.907	25.54
M3B	25	0.216	3.462	0.065	77.574	25.67
M3B	27.5	0.195	3.200	0.068	77.451	25.60
M3B	27.5	0.203	3.320	0.067	76.878	25.71
M3B	27.5	0.198	2.888	0.071	77.726	25.66
M3B	30	0.162	2.804	0.067	72.705	27.13
M3B	30	0.156	2.854	0.068	72.142	27.31
M3B	30	0.158	2.995	0.063	71.953	27.29

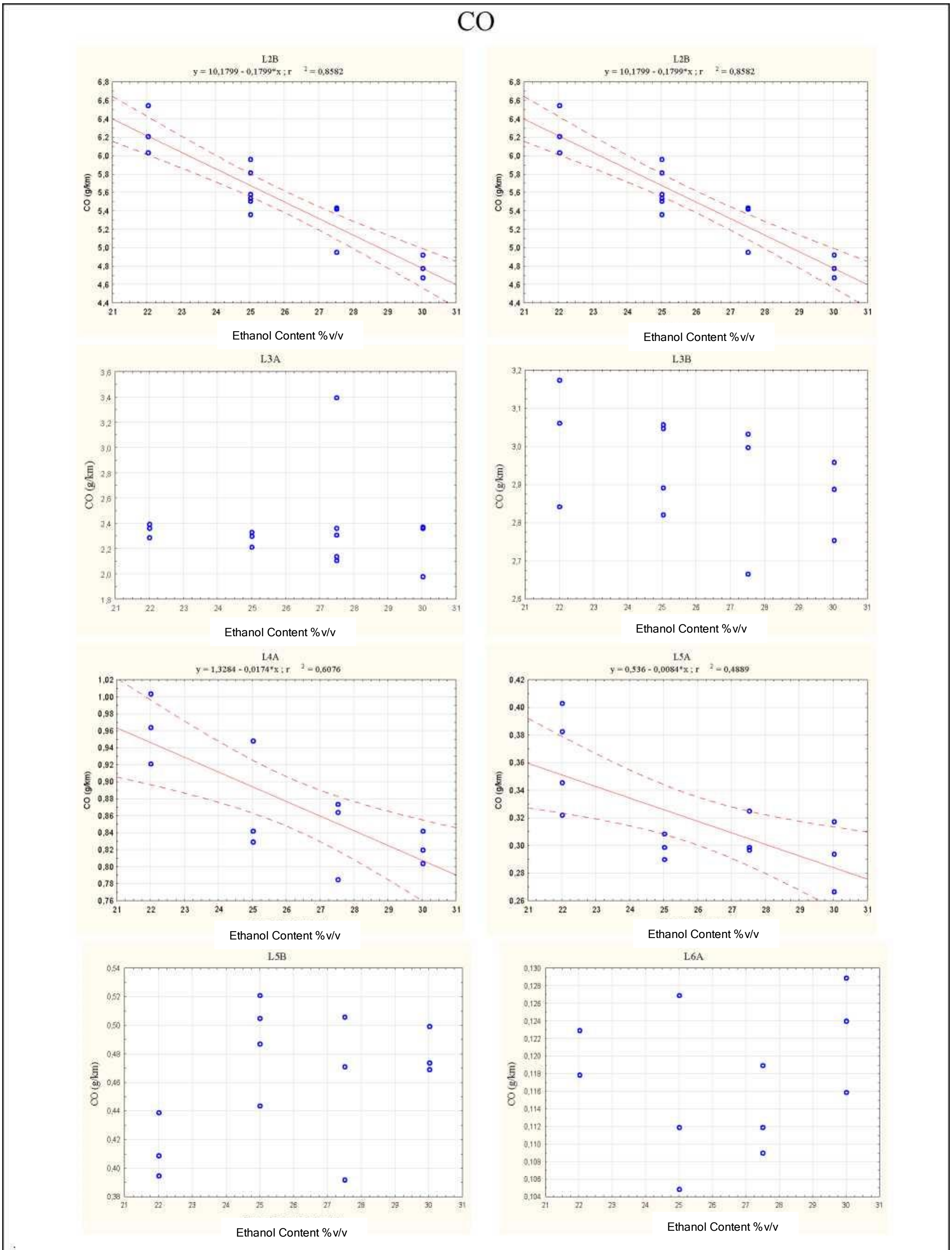
Graph representation of the Experimental Points, Linear Regression and Error of Fit for the Vehicles

THC (L2, L3) and NMHC (L4, L5 and L6)



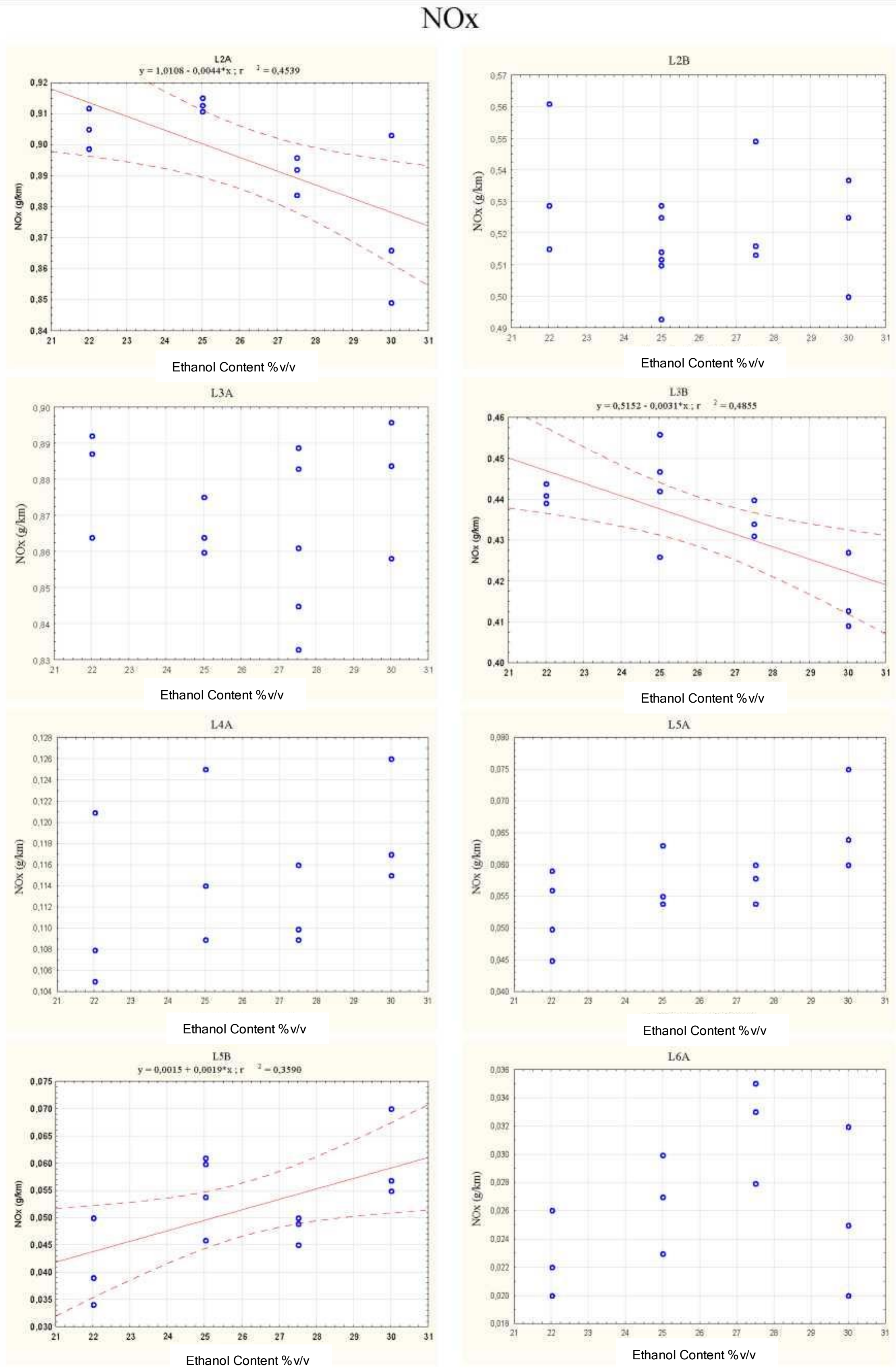
Note: The regression models of the L4A and L5B vehicles were not presented because ANOVA did not indicate that the influence of the fuel is significant at a p ≤ 0.05 level.

Figure 43 – THC Emissions (L2, L3) and NMHC (L4, L5 and L6)



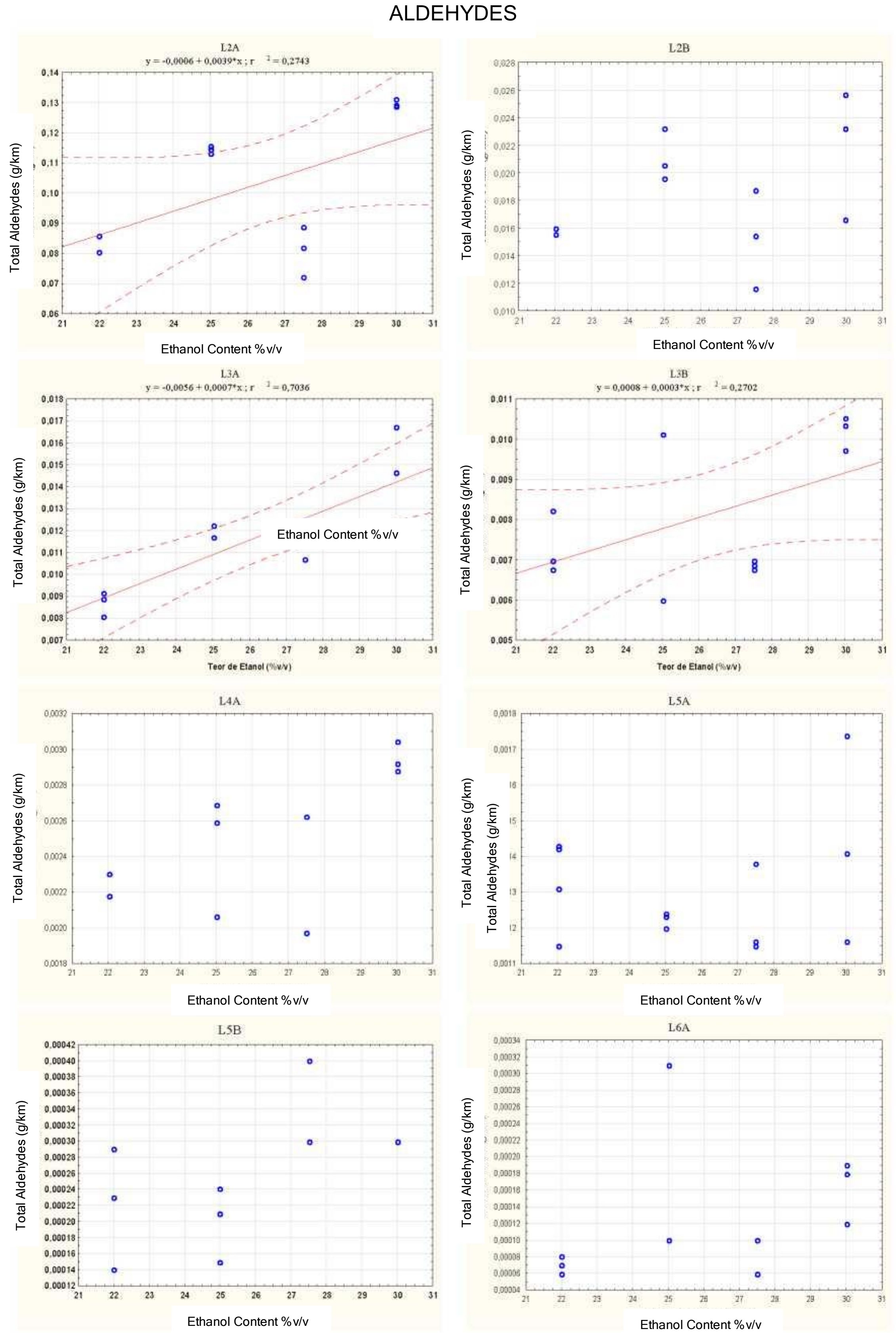
Note: The regression models of the L3A, L3B, L5B and L6A vehicles were not presented because ANOVA did not indicate that the influence of the fuel is significant at a $p \leq 0.05$ level.

Figure 44 – CO Emissions in the tested vehicles



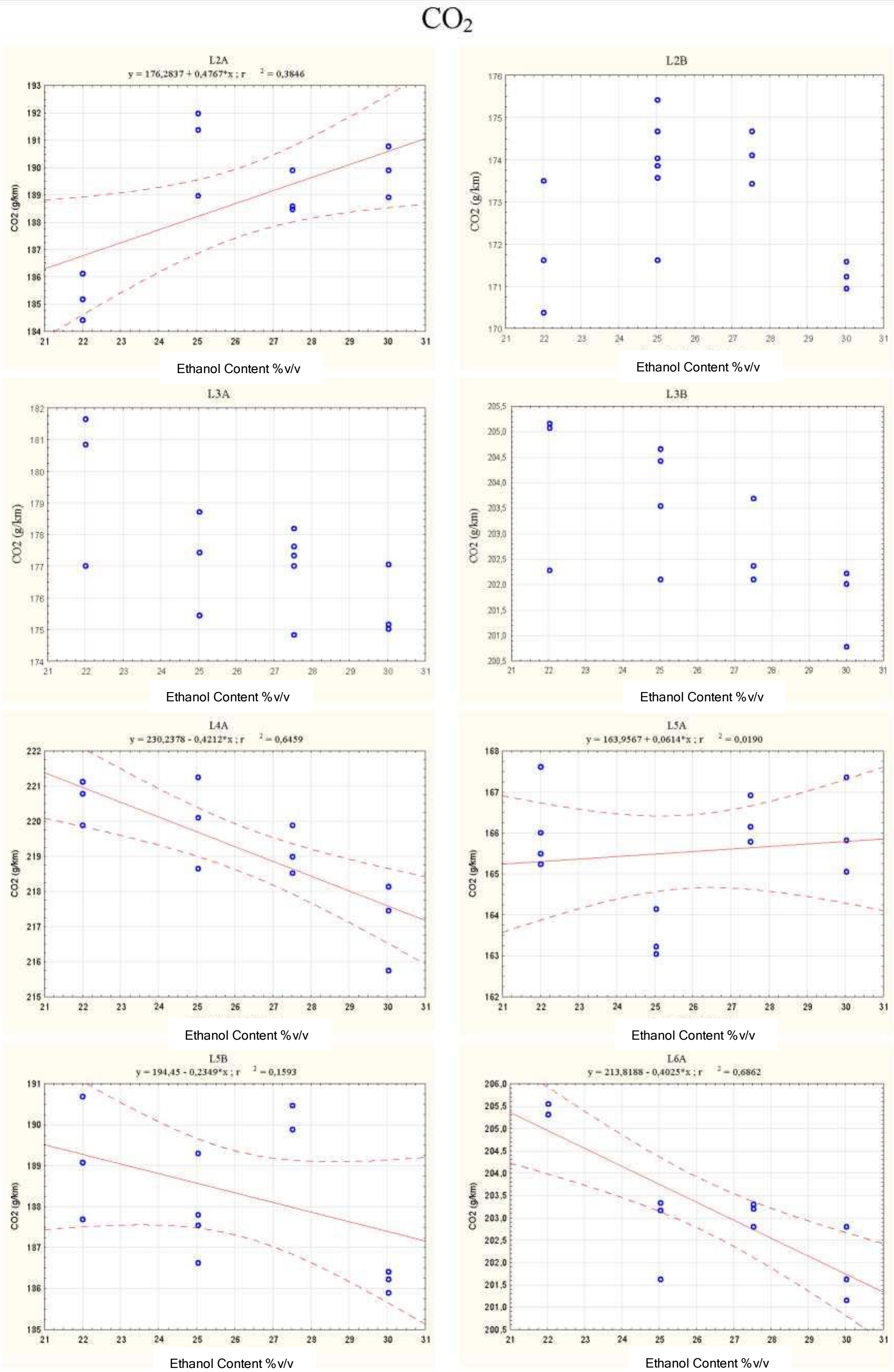
Note: The regression models of the L2B, L4A, L5A, L5B and L6A vehicles were not presented because ANOVA did not indicate that the influence of the fuel is significant at a p ≤ 0.05 level.

Figure 45 – Nox emissions (g/km) in the tested vehicles



Note: The regression models of the L2B, L4A, L5A, L5B and L6A vehicles were not presented because ANOVA did not indicate that the influence of the fuel is significant at a p ≤ 0.05 level.

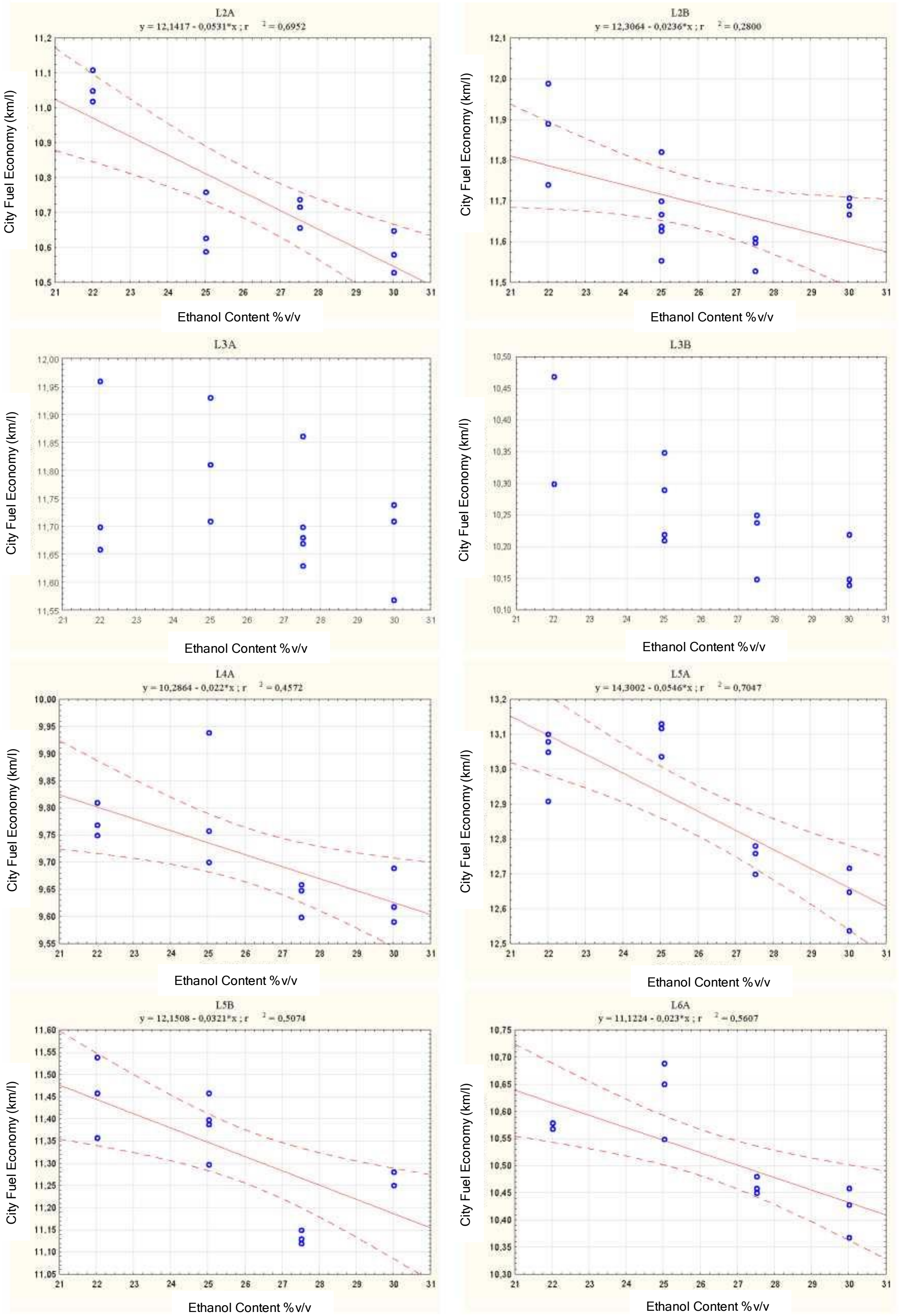
Figure 46 – Emissions of Aldehydes (g/km) in the tested vehicles.



Note: The regression models of the M2A and M3A motorcycles were not presented because ANOVA did not indicate that the influence of the fuel is significant at a $p \leq 0.05$ level.

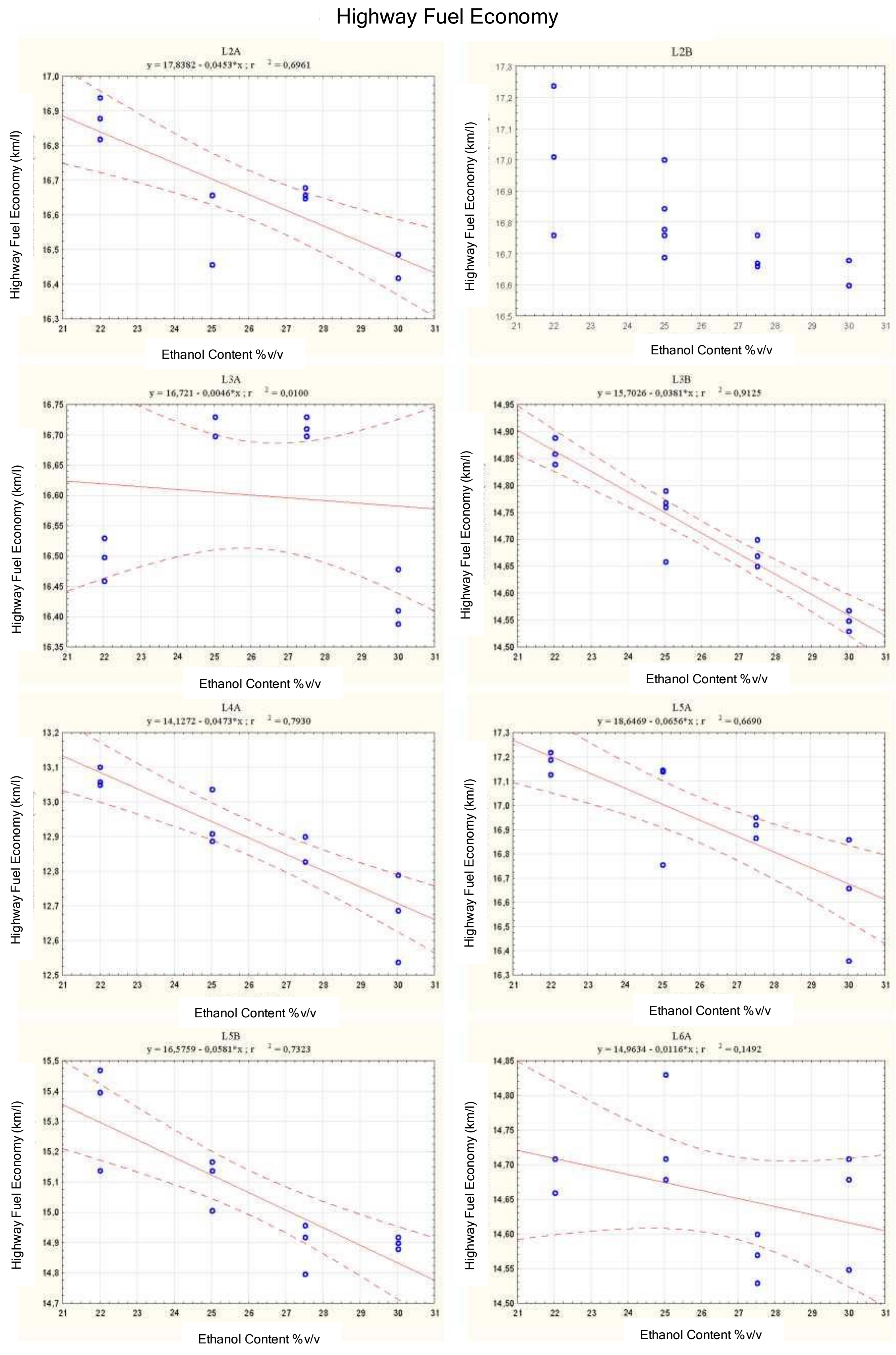
Figure 47 – Emissions of CO2 (g/km) in the tested vehicles.

“CITY” FUEL ECONOMY



Note: The regression models of the M2A and M3A motorcycles were not presented because ANOVA did not indicate that the influence of the fuel is significant at a p ≤ 0.05 level.

Figure 48 – City Fuel Economy (km/l) in the tested vehicles.



Note: The regression models of the M2A and M3A motorcycles were not presented because ANOVA did not indicate that the influence of the fuel is significant at a p ≤ 0.05 level.

Figure 49 – Highway Fuel Economy (km/l) in the tested vehicles.

Graph Representation of Experimental Points, Linear Regression and Error of Fit for the Motorcycles

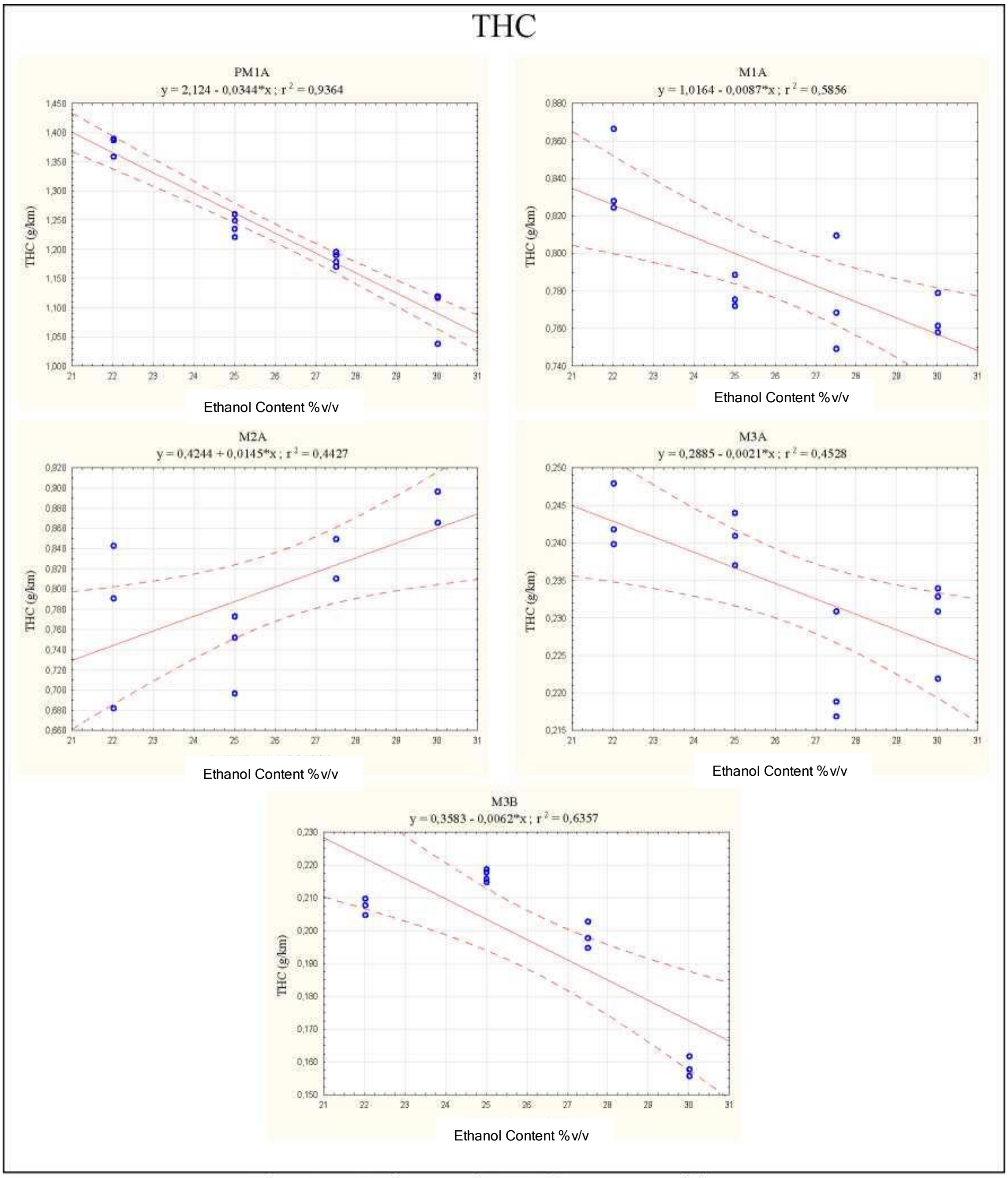


Figure 50 - THC emissions in the motorcycles.

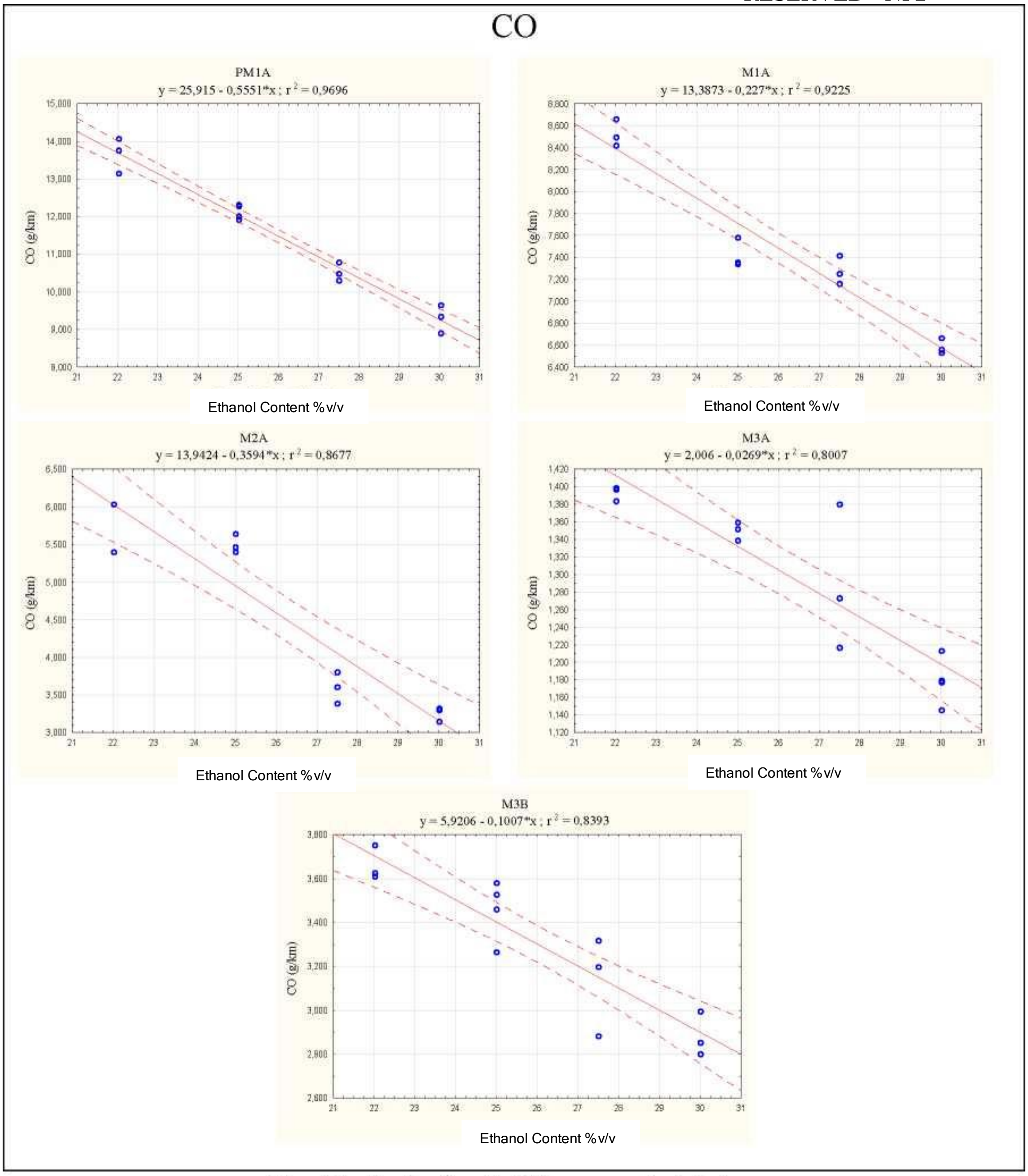
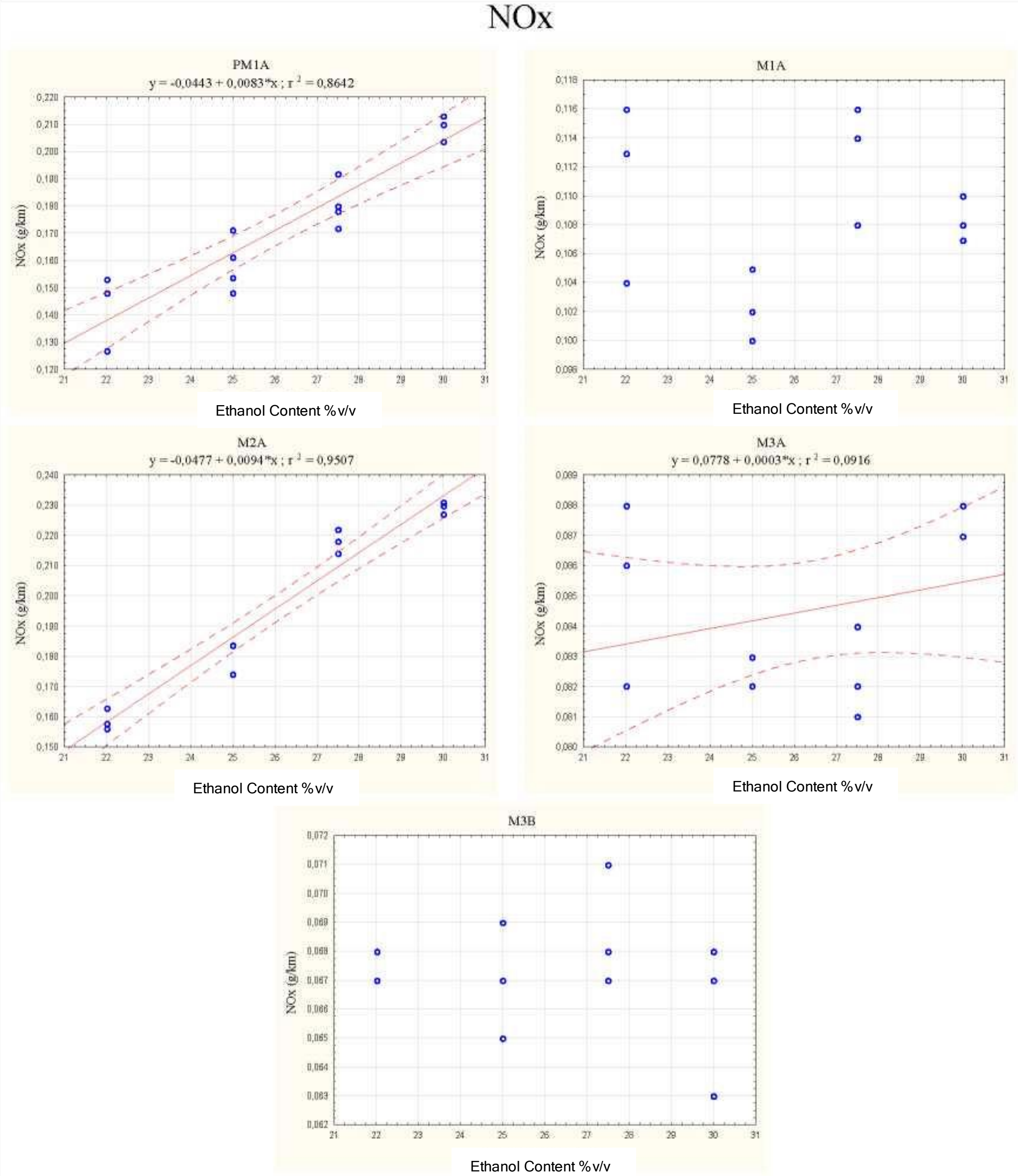
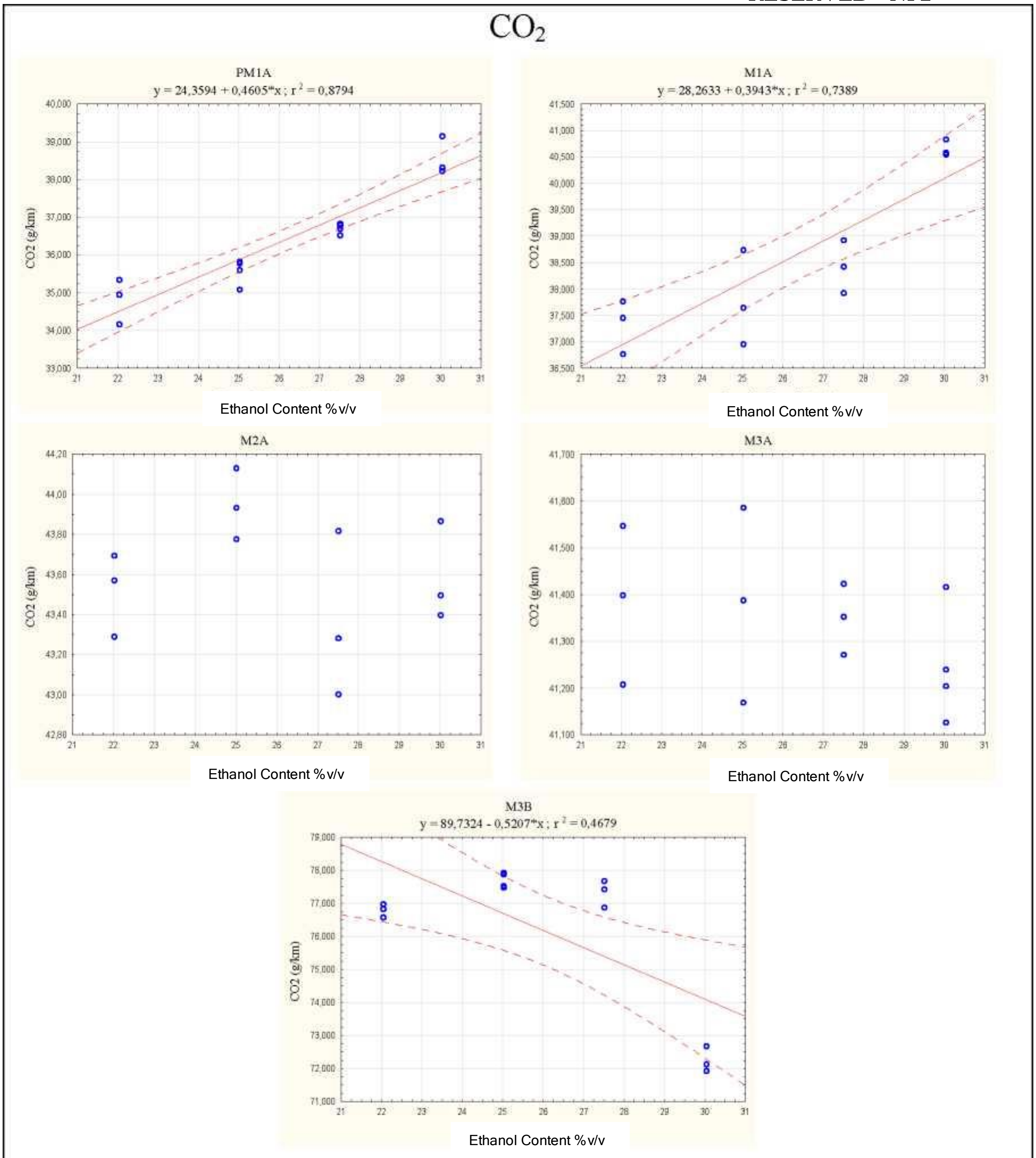


Fig. 51- Emissões de CO nas motocicletas.



Note: The regression models of the M1A and M3B motorcycles were not presented because ANOVA did not indicate that the influence of the fuel is significant at a $p \leq 0.05$ level.

Fig. 52 - Emissões de NOx nas motocicletas.



Note: The regression models of the M2A and M3A motorcycles were not presented because ANOVA did not indicate that the influence of the fuel is significant at a $p \leq 0.05$ level.

Figure 53 – CO2 Emissions in motorcycles.

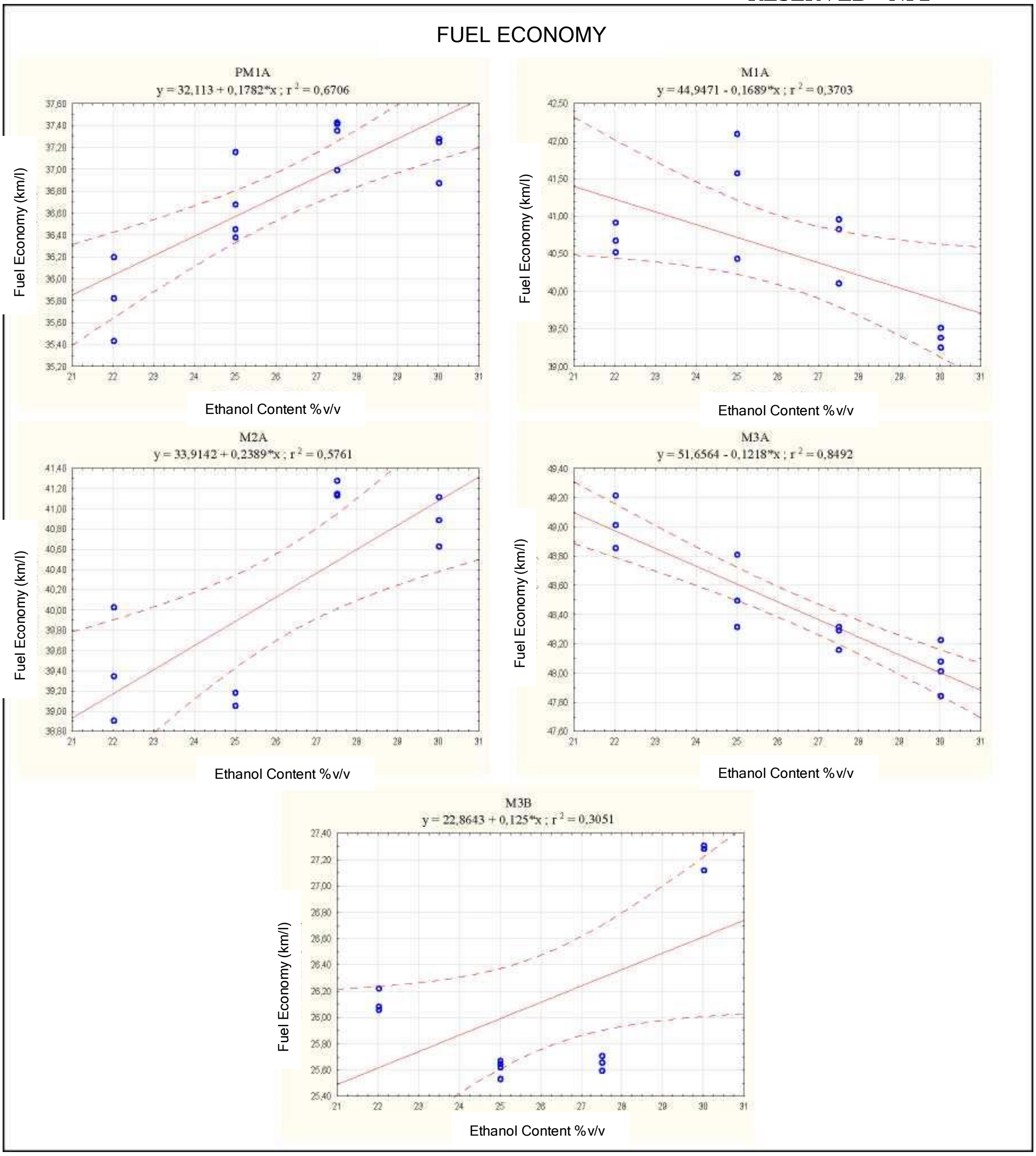


Figure 54 - Fuel economy in motorcycles.

BR

Regression Values for Vehicles

Variables	Linear Regression Values	Vehicles							
		L2A	L2B	L3A	L3B	L4A	L5A	L5B	L6A
THC (L2, L3) & NMHC (L4, L5, L6)	Linear Coefficient	1.826E+00	6.034E-01	3.734E-01	4.099E-01	NA	6.260E-02	NA	7.000E-03
	Angular Coefficient	-1.250E-02	-6.000E-03	-7.000E-04	-4.200E-03	NA	-1.200E-03	NA	7.000E-05
	E22	1,551	0.471	0.358	0.318	NA	0.036	NA	0.009
	Conf.Int. E22	0.072	0.020	0.015	0.019	NA	0.005	NA	0.001
	E25	1.514	0.453	0.356	0.305	NA	0.033	NA	0.009
	Conf.Int. E25	0.045	0.012	0.009	0.011	NA	0.003	NA	0.001
	E27.5	1.483	0.438	0.354	0.294	NA	0.030	NA	0.009
	Conf.Int. E27.5	0.047	0.013	0.009	0.012	NA	0.003	NA	0.001
	E30	1.451	0.423	0.352	0.284	NA	0.027	NA	0.009
	Conf.Int. E30	0.069	0.021	0.013	0.018	NA	0.005	NA	0.001
CO	Linear Coefficient	7.624E+00	1.018E+01	NA	NA	1.328E+00	5.360E-01	NA	NA
	Angular Coefficient	-1.585E-01	-1.799E-01	NA	NA	-1.740E-02	-8.400E-03	NA	NA
	E22	4.137	6.222	NA	NA	0.946	0.351	NA	NA
	I nt.conf. E22	0.164	0.243	NA	NA	0.037	0.033	NA	NA
	E25	3.661	5.682	NA	NA	0.893	0.326	NA	NA
	Conf Int. E25	0.102	0.146	NA	NA	0.033	0.021	NA	NA
	E27.5	3.265	5.233	NA	NA	0.850	0.305	NA	NA
	Conf.Int. E27.5	0.106	0.161	NA	NA	0.033	0.023	NA	NA
	E30	2.869	4.783	NA	NA	0.806	0.284	NA	NA
	Int.conf. E30	0.158	0.252	NA	NA	0.037	0.035	NA	NA
NOx	Linear Coefficient	1.011E+00	NA	NA	5.152E-01	NA	NA	1.500E-03	NA
	Angular Coefficient	-4.400E-03	NA	NA	-3.100E-03	NA	NA	1.900E-03	NA
	E22	0.914	NA	NA	0.447	NA	NA	0.043	NA
	Conf. Int. E22	0.020	NA	NA	0.012	NA	NA	0.010	NA
	E25	0.901	NA	NA	0.438	NA	NA	0.049	NA
	Conf. Int. E25	0.013	NA	NA	0.008	NA	NA	0.006	NA
	E27.5	0.890	NA	NA	0.430	NA	NA	0.054	NA
	Conf.Int. E27.5	0.013	NA	NA	0.008	NA	NA	0.006	NA
	E30	0.879	NA	NA	0.422	NA	NA	0.059	NA
	Conf. Int. E30	0.020	NA	NA	0.012	NA	NA	0.010	NA
Aldehydes	Linear Coefficient	-6.000E-04	NA	-5.600E-03	8.000E-04	5.000E-04	NA	-1.000E-04	NA
	Angular Coefficient	3.900E-03	NA	7.000E-04	3.000E-04	8.000E-05	NA	1.000E-05	NA
	E22	0.08520	NA	0.00980	0.00740	0.00226	NA	0.00012	NA
	Conf.Int. E22	0.03046	NA	0.00217	0.00214	0.00038	NA	0.00009	NA
	E25	0.09690	NA	0.01190	0.00830	0.00250	NA	0.00015	NA
	Conf.Int. E25	0.01829	NA	0.00141	0.00135	0.00024	NA	0.00006	NA
	E27.5	0.10665	NA	0.01365	0.00905	0.00270	NA	0.00018	NA
	Conf.Int. E27.5	0.01713	NA	0.00146	0.00136	0.00026	NA	0.00007	NA
	E30	0.11640	NA	0.01540	0.00980	0.00290	NA	0.00020	NA
	Conf.Int. E30	0.02577	NA	0.00211	0.00199	0.00038	NA	0.00011	NA
CO_2	Linear Coefficient	1.763E+02	NA	NA	NA	2.302E+02	1.640E+02	1.945E+02	2.138E+02
	Angular Coefficient	4.767E-01	NA	NA	NA	-4.212E-01	6.140E-02	-2.349E-01	-4.025E-01
	E22	186.77	NA	NA	NA	220.97	165.31	189.28	204.96
	Conf.Int. E22	2.55	NA	NA	NA	0.83	1.68	2.09	1.15
	E25	188.20	NA	NA	NA	219.71	165.49	188.58	203.76
	Conf.Int. E25	1.59	NA	NA	NA	0.74	1.09	1.29	0.72
	E27.5	189.39	NA	NA	NA	218.65	165.65	187.99	202.75
	Conf.Int. E27.5	1.64	NA	NA	NA	0.74	1.20	1.36	0.74
	E30	190.58	NA	NA	NA	217.60	165.80	187.40	201.74
	Conf.Int. E30	2.45	NA	NA	NA	0.82	1.79	2.06	1.11
Fuel economy - "City"	Linear Coefficient	1.214E+01	1.231E+01	NA	NA	1.029E+01	1.430E+01	1.215E+01	1.112E+01
	Angular Coefficient	-5.310E-02	-2.360E-02	NA	NA	-2.200E-02	-5.460E-02	-3.210E-02	-2.300E-02
	E22	10.97	11.79	NA	NA	9.80	13.10	11.44	10.62
	Conf.Int. E22	0.15	0.13	NA	NA	0.06	0.13	0.12	0.09
	E25	10,81	11,72	NA	NA	9,74	12,94	11,35	10,55
	Conf.Int. E25	0.09	0.08	NA	NA	0.06	0.09	0.08	0.05
	E27.5	10.68	11.66	NA	NA	9.68	12.80	11.27	10.49
	Conf.Int. E27.5	0.10	0.08	NA	NA	0.06	0.10	0.08	0.06
	E30	10.55	11.60	NA	NA	9.63	12.66	11.19	10.43
	Conf.Int. E30	0.14	0.13	NA	NA	0.06	0.14	0.12	0.08
Highway Fuel Economy	Linear Coefficient	1.784E+01	NA	1.672E+01	1.570E+01	1.413E+01	1.865E+01	1.658E+01	1.496E+01
	Angular Coefficient	-4.530E-02	NA	-4.600E-03	-3.810E-02	-4.730E-02	-6.560E-02	-5.810E-02	-1.160E-02
	E22	16.84	NA	16.62	14.86	13.09	17.20	15.30	14.71
	Conf.Int. E22	0.14	NA	0.18	0.05	0.06	0.18	0.15	0.13
	E25	16.71	NA	16.61	14.75	12.94	17.01	15.12	14.67
	Conf.Int. E25	0.09	NA	0.11	0.03	0.06	0.11	0.09	0.08
	E27.5	16.59	NA	16.59	14.65	12.83	16.84	14.98	14.64
	Conf.Int. E27.5	0.09	NA	0.11	0.03	0.06	0.13	0.10	0.07
	E30	16.48	NA	16.58	14.56	12.71	16.68	14.83	14.62
	Conf.Int. E30	0.13	NA	0.17	0.05	0.06	0.19	0.14	0.11

Note: NA - not assessed because no significant difference was pointed out by ANOVA ($p < 0.05$),

Regression Values for Motorcycles

Variables	Linear Regression Values	Motorcycles				
		PM1A	M1A	M2A	M3A	M3B
THC	Linear Coefficient	2.124E+00	1.016E+00	4.244E-01	2.885E-01	3.583E-01
	Angular Coefficient	-3.440E-02	-8.700E-03	1.450E-02	-2.100E-03	-6.200E-03
	E22	1.367	0.825	0.743	0.242	0.222
	Conf.Int. E22	0.033	0.031	0.069	0.010	0.018
	E25	1.264	0.799	0.787	0.236	0.203
	Conf.Int. E25	0.020	0.019	0.043	0.006	0.011
	E27.5	1.178	0.777	0.823	0.231	0.188
	Conf.Int. E27.5	0.021	0.020	0.044	0.006	0.012
	E30	1.092	0.755	0.859	0.226	0.172
	Conf.Int. E30	0.032	0.030	0.066	0.008	0.018
CO	Linear Coefficient	2.592E+01	1.339E+01	1.394E+01	2.006E+00	5.921E+00
	Angular Coefficient	-5.551E-01	-2.270E-01	-3.594E-01	-2.690E-02	-1.007E-01
	E22	13.703	8.393	6.036	1.414	3.705
	Conf.Int. E22	0.363	0.278	0.594	0.056	0.171
	E25	12.038	7.712	4.957	1.334	3.403
	Conf.Int. E25	0.219	0.174	0.371	0.035	0.105
	E27.5	10.650	7.145	4.059	1.266	3.151
	Conf.Int. E27.5	0.225	0.179	0.382	0.034	0.111
	E30	9.262	6.577	3.160	1.199	2.900
	Conf.Int. E30	0.346	0.267	0.570	0.049	0.168
NOx	Linear Coefficient	-4.430E-02	NA	-4.770E-02	7.780E-02	NA
	Angular Coefficient	8.300E-03	NA	9.400E-03	3.000E-04	NA
	E22	0.138	NA	0.159	0.084	NA
	Conf.Int. E22	0.012	NA	0.009	0.003	NA
	E25	0.163	NA	0.187	0.085	NA
	Conf.Int. E25	0.007	NA	0.006	0.002	NA
	E27.5	0.184	NA	0.211	0.086	NA
	Conf.Int. E27.5	0.008	NA	0.006	0.002	NA
	E30	0.205	NA	0.234	0.087	NA
	Conf.Int. E30	0.012	NA	0.009	0.003	NA
CO2	Linear Coefficient	2.436E+01	2.826E+01	NA	NA	8.973E+01
	Angular Coefficient	4.605E-01	3.943E-01	NA	NA	-5.207E-01
	E22	34.49	36.94	NA	NA	78.28
	Conf.Int. E22	0.63	0.99	NA	NA	2.15
	E25	35.87	38.12	NA	NA	76.71
	Conf.Int. E25	0.38	0.62	NA	NA	1.32
	E27.5	37.02	39.11	NA	NA	75.41
	Conf.Int. E27.5	0.39	0.64	NA	NA	1.40
	E30	38.17	40.09	NA	NA	74.11
	Conf.Int. E30	0.60	0.95	NA	NA	2.12
Fuel economy	Angular Coefficient	3.211E+01	4.495E+01	3.391E+01	5.166E+01	2.286E+01
	Angular Coefficient	1.782E-01	-1.689E-01	2.389E-01	-1.218E-01	1.250E-01
	E22	36.03	41.23	39.17	48.98	25.61
	Conf.Int. E22	0,46	0,93	0,87	0,22	0,73
	E25	36,57	40,72	39,89	48,61	25,99
	Conf.Int. E25	0,28	0,58	0,54	0,13	0,45
	E27.5	37,01	40,30	40,48	48,31	26,30
	Conf.Int. E27.5	0,29	0,60	0,56	0,13	0,47
	E30	37,46	39,88	41,08	48,00	26,61
	Conf.Int. E30	0,44	0,90	0,83	0,19	0,72

Note: NA - not assessed because no significant difference was identified by ANOVA ($p < 0.05$),

ANNEX IV

RESULTS OF THE TRACK PERFORMANCE TESTS

Average results of the track speed recovery times for the E25, E27.5 and E30 fuels in the test vehicles

L2B	Time (s)		
	40-80	60-100	80-120
E25	8.5	13.4	23.3
E27,5	8.7	13.6	23.2
E30	8.6	13.6	23.3

L4A	Time (s)		
	40-80	60-100	80-120
E25	7,6	12.1	23.7
E27,5	7,5	12.1	23.7
E30	7,4	12.0	23.7

L3A	Time (s)		
	40-80	60-100	80-120
E25	7.4	7.8	11.4
E27,5	7.5	7.8	11.3
E30	7.5	7.8	11.4

L5A	Time (s)		
	40-80	60-100	80-120
E25	7,9	11.1	16.2
E27,5	7,8	11.0	16.1
E30	7,7	11.0	16.0

L3B	Time (s)		
	40-80	60-100	80-120
E25	11.2	17.9	33.3
E27.5	11.1	17.7	32.7
E30	11.4	18.1	32.7

L5B	Time (s)		
	40-80	60-100	80-120
E25	5.9	7.1	8.7
E27,5	6.0	7.2	8.8
E30	6.1	7.1	9.0

L6B	Time (s)		
	40-80	60-100	80-120
E25	5.2	6.2	7.5
E27,5	5.2	6.1	7.4
E30	5.0	6.0	7.3

ANNEX V

RESULTS OF THE TYPICAL CURVES IN ENGINES

FULL LOAD

Corrected power (kW)

Power	1400	2000	2500	3000	3500	4000	4500	5000	5800	6000
E25	37.49	54.01	68.39	79.90	92.17	103.51	110.77	116.31	120.33	121.08
E25	37.61	54.32	68.64	80.06	92.39	103.46	110.87	116.82	120.51	121.49
E25	37.75	55.13	68.62	80.17	92.35	103.68	110.79	117.21	120.91	121.46
E27.5	37.19	52.84	67.53	79.76	91.46	102.62	110.08	115.60	119.76	120.53
E27.5	37.46	53.59	67.84	79.89	92.15	103.26	110.63	116.53	120.16	121.17
E27.5	37.34	53.21	68.30	80.44	92.28	104.20	110.57	116.60	120.45	121.51
E30	37.77	53.72	68.88	80.08	92.07	104.25	110.73	116.87	120.87	121.63
E30	37.86	53.53	68.74	80.36	92.26	103.84	111.22	116.98	121.05	121.53
E30	38.02	53.53	68.81	80.34	91.77	103.66	110.88	116.49	120.65	121.47

Statistically significant differences_Power

1400 rpm	E 25	E 27.5	E 30
E 25		-0.8%	0.7%
E 27.5	0.8%		1.5%
E 30	-0.7%	-1.5%	

2000 rpm	E 25	E 27.5	E 30
E 25		-2.3%	-1.6%
E 27.5	2.4%		=
E 30	1.7%	=	

2500 rpm	E 25	E 27.5	E 30
E 25		-1.0%	=
E 27.5	1.0%		1.4%
E 30	=	-1.3%	

3000 rpm	E 25	E 27.5	E 30
E 25		=	=
E 27.5	=		=
E 30	=	=	

3500 rpm	E 25	E 27.5	E 30
E 25		=	=
E 27.5	=		=
E 30	=	=	

4000 rpm	E 25	E 27.5	E 30
E 25		=	=
E 27.5	=		=
E 30	=	=	

4500 rpm	E 25	E 27.5	E 30
E 25		=	=
E 27.5	=		0.5%
E 30	=	-0.5%	

5000 rpm	E 25	E 27.5	E 30
E 25		=	=
E 27.5	=		=
E 30	=	=	

5800 rpm	E 25	E 27.5	E 30
E 25		=	=
E 27.5	=		0.6%
E 30	=	-0.6%	

6000 rpm	E 25	E 27.5	E 30
E 25		=	=
E 27.5	=		=
E 30	=	=	

PETROBRAS Specific Fuel Consumption (g/kWh) - FULL LOAD RESERVED - NP2

Specific Consumption	1400	2000	2500	3000	3500	4000	4500	5000	5800	6000
E25	277.55	258.85	255.18	264.99	269.48	318.45	317.03	314.77	332.50	344.76
E25	279.55	262.05	254.65	264.66	269.25	319.92	317.80	313.51	333.80	343.23
E25	276.54	267.47	256.31	263.51	268.12	316.98	319.42	312.35	330.97	342.15
E27.5	282.38	259.06	260.61	269.06	275.26	326.17	325.20	321.32	339.84	351.09
E27.5	280.21	258.60	260.90	270.03	275.35	325.29	325.31	319.67	338.90	348.18
E27.5	279.99	258.15	258.87	268.45	275.24	321.68	327.96	320.66	340.09	349.14
E30	281.66	261.16	258.44	269.55	275.29	320.11	324.33	319.36	337.32	342.33
E30	282.88	258.52	259.83	270.07	275.38	324.20	324.45	319.75	338.28	343.68
E30	281.60	258.85	259.90	269.59	276.20	323.02	323.21	319.79	339.82	347.36

Statistically significant differences, Specific consumption

1400 rpm	E 25	E 27.5	E 30
E 25		1.1%	1.5%
E 27.5	-1.1%		=
E 30	-1.5%	=	

2000 rpm	E 25	E 27.5	E 30
E 25		=	=
E 27.5	=		=
E 30	=	=	

2500 rpm	E 25	E 27.5	E 30
E 25		1.9%	1.6%
E 27.5	-1.8%		=
E 30	-1.5%	=	

3000 rpm	E 25	E 27.5	E 30
E 25		1.8%	2.0%
E 27.5	-1.8%		=
E 30	-2.0%	=	

3500 rpm	E 25	E 27.5	E 30
E 25		2.4%	2.5%
E 27.5	-2.3%		=
E 30	-2.4%	=	

4000 rpm	E 25	E 27.5	E 30
E 25		1.9%	=
E 27.5	-1.8%		=
E 30	=	=	

4500 rpm	E 25	E 27.5	E 30
E 25		2.5%	1.9%
E 27.5	-2.5%		=
E 30	-1.8%	=	

5000 rpm	E 25	E 27.5	E 30
E 25		2.2%	1.9%
E 27.5	-2.2%		=
E 30	-1.9%	=	

5800 rpm	E 25	E 27.5	E 30
E 25		2.2%	1.8%
E 27.5	-2.1%		=
E 30	-1.8%	=	

6000 rpm	E 25	E 27.5	E 30
E 25		1.8%	=
E 27.5	-1.7%		-1.4%
E 30	=	1.5%	

Exhaust temperature before the catalytic converter (°C) - FULL LOAD

Exhaust Temperature	1400	2000	2500	3000	3500	4000	4500	5000	5800	6000
E25	784.00	785.00	839.00	901.00	900.00	913.00	914.00	912.00	907.00	884.00
E25	783.00	781.00	838.00	900.00	899.00	914.00	913.00	911.00	906.00	882.00
E25	784.00	779.00	839.00	900.00	901.00	915.00	916.00	910.00	906.00	885.00
E27.5	779.00	790.00	841.00	902.00	907.00	917.00	917.00	912.00	905.00	880.00
E27.5	776.00	789.00	841.00	902.00	907.00	913.00	914.00	910.00	904.00	882.00
E27.5	773.00	786.00	837.00	897.00	899.00	908.00	911.00	905.00	902.00	880.00
E30	775.00	788.00	836.00	901.00	902.00	911.00	915.00	912.00	908.00	885.00
E30	776.00	788.00	836.00	899.00	901.00	909.00	910.00	909.00	904.00	883.00
E30	776.00	789.00	835.00	901.00	903.00	911.00	914.00	912.00	907.00	882.00

Statistically significant differences, Exhaust Temperature

1400 rpm	E 25	E 27.5	E 30
E 25		-1.0%	-1.0%
E 27.5	1.0%		=
E 30	1.0%	=	

2000 rpm	E 25	E 27.5	E 30
E 25		0.9%	0.9%
E 27.5	-0.8%		=
E 30	-0.8%	=	

2500 rpm	E 25	E 27.5	E 30
E 25		=	-0.4%
E 27.5	=		-0.5%
E 30	0.4%	0.5%	

3000 rpm	E 25	E 27.5	E 30
E 25		=	=
E 27.5	=		=
E 30	=	=	

3500 rpm	E 25	E 27.5	E 30
E 25		=	=
E 27.5	=		=
E 30	=	=	

4000 rpm	E 25	E 27.5	E 30
E 25		=	=
E 27.5	=		=
E 30	=	=	

4500 rpm	E 25	E 27.5	E 30
E 25		=	=
E 27.5	=		=
E 30	=	=	

5000 rpm	E 25	E 27.5	E 30
E 25		=	=
E 27.5	=		=
E 30	=	=	

5800 rpm	E 25	E 27.5	E 30
E 25		=	=
E 27.5	=		=
E 30	=	=	

6000 rpm	E 25	E 27.5	E 30
E 25		-0.3%	=
E 27.5	0.3%		=
E 30	=	=	

Lambda - FULL LOAD

Lambda	1400	2000	2500	3000	3500	4000	4500	5000	5800	6000
E25	1.00	0.98	1.00	1.00	0.97	0.90	0.90	0.90	0.89	0.86
E25	1.00	0.97	1.00	1.00	0.97	0.90	0.90	0.90	0.88	0.86
E25	1.00	0.96	1.00	1.00	0.97	0.90	0.90	0.90	0.88	0.86
E27.5	1.00	0.99	1.00	1.00	0.97	0.90	0.90	0.90	0.88	0.86
E27.5	0.99	0.99	1.00	1.00	0.97	0.90	0.90	0.90	0.88	0.86
E27.5	1.00	0.99	1.00	1.00	0.96	0.90	0.89	0.90	0.88	0.86
E30	1.00	0.99	1.00	1.00	0.97	0.90	0.90	0.91	0.89	0.87
E30	1.00	1.00	1.00	1.00	0.97	0.90	0.89	0.90	0.88	0.87
E30	1.00	1.00	1.00	1.00	0.97	0.90	0.90	0.90	0.89	0.86

Differences_Lambda

(It was not possible to apply ANOVA due to the non-existence of variance in some conditions)

1400 rpm	E 25	E 27.5	E 30
E 25		0.0%	0.0%
E 27.5	0.0%		0.0%
E 30	0.0%	0.0%	

2000 rpm	E 25	E 27.5	E 30
E 25		1.0%	1.0%
E 27.5	-1.0%		0.0%
E 30	-1.0%	0.0%	

2500 rpm	E 25	E 27.5	E 30
E 25		0.0%	0.0%
E 27.5	0.0%		0.0%
E 30	0.0%	0.0%	

3000 rpm	E 25	E 27.5	E 30
E 25		0.0%	0.0%
E 27.5	0.0%		0.0%
E 30	0.0%	0.0%	

3500 rpm	E 25	E 27.5	E 30
E 25		0.0%	0.0%
E 27.5	0.0%		0.0%
E 30	0.0%	0.0%	

4000 rpm	E 25	E 27.5	E 30
E 25		0.0%	0.0%
E 27.5	0.0%		0.0%
E 30	0.0%	0.0%	

4500 rpm	E 25	E 27.5	E 30
E 25		0.0%	0.0%
E 27.5	0.0%		0.0%
E 30	0.0%	0.0%	

5000 rpm	E 25	E 27.5	E 30
E 25		0.0%	1.1%
E 27.5	0.0%		1.1%
E 30	-1.1%	-1.1%	

5800 rpm	E 25	E 27.5	E 30
E 25		-1.1%	0.0%
E 27.5	1.1%		1.1%
E 30	0.0%	-1.1%	

6000 rpm	E 25	E 27.5	E 30
E 25		0.0%	1.2%
E 27.5	0.0%		1.2%
E 30	-1.1%	-1.1%	

PETROBRAS

PARTIAL LOAD (50%)
Specific fuel consumption (g/kWh)

	1400	2000	2500	3000	3500	4000	4500	5000	5800	6000
E25	253.9	253.0	256.2	256.9	257.3	264.7	272.2	278.4	299.5	305.4
E25	250.6	245.6	251.8	253.7	255.2	262.8	269.1	276.7	300.6	305.0
E25	251.8	249.6	251.6	252.8	254.2	263.2	268.3	276.9	300.6	305.5
E27.5	255.52	255.36	259.06	261.65	263.90	271.86	277.68	285.38	309.36	315.47
E27.5	254.64	247.40	255.43	258.97	258.46	267.31	275.65	283.93	306.05	309.97
E27.5	252.67	247.91	256.21	257.14	258.14	267.48	273.62	281.62	304.94	309.43
E30	255.51	253.82	258.64	260.94	261.64	268.85	274.97	283.21	306.60	310.16
E30	255.79	249.12	255.56	258.97	259.18	266.88	272.68	281.95	306.73	310.46
E30	256.51	250.15	255.50	258.82	259.66	269.02	274.12	281.53	306.17	310.67

Statistically significant differences – Specific Consumption

1400 rpm	E 25	E 27.5	E 30
E 25		=	1.5%
E 27.5	=		=
E 30	-1.5%	=	

2000 rpm	E 25	E 27.5	E 30
E 25		=	=
E 27.5	=		=
E 30	=	=	

2500 rpm	E 25	E 27.5	E 30
E 25		=	=
E 27.5	=		=
E 30	=	=	

3000 rpm	E 25	E 27.5	E 30
E 25			2.0%
1.9%			
E 27.5	-1.8%		=
E 30	-2.0%	=	

3500 rpm	E 25	E 27.5	E 30
E 25		1.8%	1.8%
E 27.5	-1.8%		=
E 30	-1.8%	=	

4000 rpm	E 25	E 27.5	E 30
E 25		2.0%	1.8%
E 27.5	-2.0%		=
E 30	-1.7%	=	

4500 rpm	E 25	E 27.5	E 30
E 25		2.2%	1.5%
E 27.5	-2.1%		=
E 30	-1.5%	=	

5000 rpm	E 25	E 27.5	E 30
E 25		2.3%	1.8%
E 27.5	-2.2%		=
E 30	-1.7%	=	

5800 rpm	E 25	E 27.5	E 30
E 25		2.2%	2.1%
E 27.5	-2.1%		=
E 30	-2.1%	=	

6000 rpm	E 25	E 27.5	E 30
E 25		2.1%	1.7%
E 27.5	-2.0%		=
E 30	-1.6%	=	

Lambda - PARTIAL LOAD

Lambda	1400	2000	2500	3000	3500	4000	4500	5000	5800	6000
E25	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
E25	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
E25	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
E27.5	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
E27.5	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
E27.5	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
E30	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
E30	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
E30	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Differences_Lambda

(It was not possible to apply ANOVA due to the non-existence of variance in all the conditions)

1400 rpm	E 25	E 27.5	E 30
E 25		0.0%	0.0%
E 27.5	0.0%		0.0%
E 30	0.0%	0.0%	

2000 rpm	E 25	E 27.5	E 30
E 25		0.0%	0.0%
E 27.5	0.0%		0.0%
E 30	0.0%	0.0%	

2500 rpm	E 25	E 27.5	E 30
E 25		0.0%	0.0%
E 27.5	0.0%		0.0%
E 30	0.0%	0.0%	

3000 rpm	E 25	E 27.5	E 30
E 25		0.0%	0.0%
E 27.5	0.0%		0.0%
E 30	0.0%	0.0%	

3500 rpm	E 25	E 27.5	E 30
E 25		0.0%	0.0%
E 27.5	0.0%		0.0%
E 30	0.0%	0.0%	

4000 rpm	E 25	E 27.5	E 30
E 25		0.0%	0.0%
E 27.5	0.0%		0.0%
E 30	0.0%	0.0%	

4500 rpm	E 25	E 27.5	E 30
E 25		0.0%	0.0%
E 27.5	0.0%		0.0%
E 30	0.0%	0.0%	

5000 rpm	E 25	E 27.5	E 30
E 25		0.0%	0.0%
E 27.5	0.0%		0.0%
E 30	0.0%	0.0%	

5800 rpm	E 25	E 27.5	E 30
E 25		0.0%	0.0%
E 27.5	0.0%		0.0%
E 30	0.0%	0.0%	

6000 rpm	E 25	E 27.5	E 30
E 25		0.0%	0.0%
E 27.5	0.0%		0.0%
E 30	0.0%	0.0%	

ANNEX VI

MOTORCYCLE PERFORMANCE TESTING REPORT - ABRACICLO

PETROBRAS

RT ABRACICLO

SUMMARY OF THE REPORT

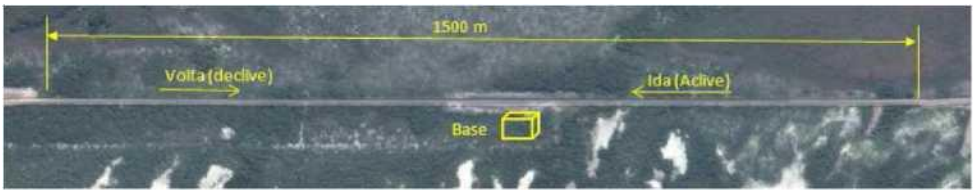
PETROBRAS

INTRODUCTION TO COLD START AND SPEED RECOVERY TESTS

Test dates: 22, 23/09 (cold start) and 24/09 (speed recovery) - Location: Restinga de Maranbaia, Army Base, RJ.

Person in Charge of the Evaluation: Ricardo Grotto de Carilargo.

Test pilot: Ezequias Borges de Menezes.



Comments:

On the initial date of the cold start tests, it was observed that the 3 motorcycles equipped with carburetors (PM1A; M1A and M2A), had functional problems (idle speed rotation unstable and below specification) and it was necessary to remove the carburetors, clean them and adjust the rotation, due to the presence of dirt in the tank, in the main nozzles and in the idle speed jet nozzles. It was also noted that the PM1A motorcycle has a non-original carburetor and exhaust, and its results may not represent most of the motorcycles in the market, but it was agreed that the tests would be performed in this way in order to assess their influence.

Abraciclo considers it necessary to reassess the data on the gas emission of these motorcycles, because with the presence of dirt, the results may vary from one test to another and deviate from what was expected.

COLD START AND COLD ENGINE DRIVABILITY IN MOTORCYCLES

Test Methodology

The tests were carried out in a refrigerated container. Each test was started when the temperatures of the engine oil reached 0°C. Before each test, the previous fuel was removed from the tank, feed system lines and carburetors. The motorcycles equipped with electronic injection were conditioned by reheating the engine at 80°C in a constant rotation at around 4000 rpm, to ensure recognition of the new fuel.

Each test consisted of the following steps, which were carried out consecutively after the motorcycles were started:

- Number of attempts to start the motorcycle, limited to 4 attempts of no more than 5 seconds each for motorcycles equipped with electric start and 4 attempts (kick start) for motorcycles equipped with a ratcheting lever. For motorcycles equipped with a carburetor, the motorcycle must be started with the choke engaged;
- Time to start, in seconds;
- Checking for engine rotation failures during start-up;
- Monitoring of the engine operation for 60 seconds after start-up. For motorcycles equipped with carburetor, maintain smooth accelerations with gear in neutral and the choke engaged;
- Accelerations (by twisting the throttle) with the motorcycle in neutral, and check for jamming or delay in deceleration;
- Riding the motorcycle, subjecting it to various conditions, such as smooth initial rolling, constant speed, abrupt accelerations, re-acceleration, abrupt braking.

Cold engine drivability with the motorcycles starting from an idle position, being accelerated smoothly and the speed being gradually increased by increments of 10 km/h until entering the red zone in each gear, checking for faults or abnormal operation;

For each step above, the test rider must write his/her comments in the respective boxes of the form below. In the event of a fault, report its severity by classifying it as minor, moderate or major. Also, describe in your own words, the type of fault observed (choke, oscillation, low rpm, engine shutdown, deceleration delay, etc ...). When no occurrence is noticed by the rider, report the step as NORMAL.

Results and Discussion

VEHICLE: M3A	TEST TECHNICIAN Ezequias Borges de Menezes			
FUEL	C068/2014 E-25%	C070/2014 E-27.5%	C072/2014 E-30%	NOTE
DATE	22/9/2014	22/9/2014	23/9/2014	
ATTEMPTS	3 attempts	2 attempts	3 attempts	
START-UP	Normal	Normal	Normal	
IDLE SPEED	Normal	Normal	Normal	
FREE ACCELERATION	Normal	Normal	Normal	
DRIVABILITY	Normal	Normal	Normal	
DATE	23/9/2014	23/9/2014	23/9/2014	
ATTEMPTS	2 attempts	3 attempts	2 attempts	
START-UP	Normal	Normal	Normal	
IDLE SPEED	Normal	Normal	Normal	
FREE ACCELERATION	Normal	Normal	Normal	
DRIVABILITY	Normal	Normal	Normal	

Comment: Pass.

VEHICLE: PMIA	TEST TECHNICIAN Ezequias Borges de Menezes			
FUEL	C068/2014 E-25%	C070/2014 E-27.5%	C072/2014 E-30%	NOTE
DATE	22/9/2014	22/9/2014	23/9/2014	Failed in the test with E-30%.
ATTEMPTS	3 attempts	4 attempts	5 attempts (severe/major).	
START-UP	Normal	Normal	Engine has difficulty in keeping operating 1 minute after starting (severe)	
IDLE SPEED	Normal	Normal	Engine has instability in idle speed rotation (moderate fault)	
FREE ACCELERATION	Normal	Normal	Normal	
DRIVABILITY	Normal	Normal	Had faults in it when it was being ridden (level	
DATE	23/9/2014	23/9/2014	23/9/2014	
ATTEMPTS	3 attempts	3 attempts	6 attempts (severe/major).	
START-UP	Normal	Normal	Engine has difficulty in keeping operating 1 minute after starting (severe/major)	
IDLE SPEED	Normal	Normal	Engine has instability in idle speed rotation (moderate fault)	
FREE ACCELERATION	Normal	Normal	Normal	
DRIVABILITY	Normal	Normal	The engine shut down when the motorcycle was beginning to roll forward and had faults in it when the motorcycle was being ridden. (major	

Comment: Under the E-30% condition, the PM1A motorcycle that has non-original parts (carburetor and exhaust) has functional problems at low temperature, indicating that it is not able to operate properly with this level of alcohol in the gasoline. Despite the working condition of the motorcycle, the tests are important because there are probably other motorcycles in the market in similar conditions that may present unsatisfactory results like this, serving as a warning about what can happen in the market if this content is adopted in the future.

PETROBRAS

VEHICLE: MIA	TEST TECHNICIAN Ezequias Borges de Menezes			
FUEL	C068/2014 E-25%	C070/2014 E-27.5%	C072/2014 E-30%	NOTE
DATE	22/9/2014	22/9/2014	23/9/2014	
ATTEMPTS	3 attempts	3 attempts	4 attempts	
START-UP	Normal	Normal	Normal	
IDLE SPEED	Normal	Normal	Normal	
FREE ACCELERATION	Normal	Normal	Normal	
DRIVABILITY	Normal	Normal	Normal	
DATE	23/9/2014	23/9/2014	23/9/2014	
ATTEMPTS	3 attempts	3 attempts	3 attempts	
START-UP	Normal	Normal	Normal	
IDLE SPEED	Normal	Normal	Normal	
FREE ACCELERATION	Normal	Normal	Normal	
DRIVABILITY	Normal	Normal	Normal	

Comment: Pass.

VEHICLE: M2A	TEST TECHNICIAN Ezequias Borges de Menezes			
FUEL	C068/2014 E-25%	C070/2014 E-27.5%	C072/2014 E-30%	NOTE
DATE	22/9/2014	22/9/2014	23/9/2014	
ATTEMPTS	3 attempts	3 attempts	4 attempts	
START-UP	Normal	Normal	Normal	
IDLE SPEED	Normal	Normal	Normal	
FREE ACCELERATION	Normal	Normal	Normal	
DRIVABILITY	Normal	Normal	Normal	
DATE	23/9/2014	23/9/2014	23/9/2014	
ATTEMPTS	3 attempts	2 attempts	4 attempts	
START-UP	Normal	Normal	Normal	
IDLE SPEED	Normal	Normal	Normal	
FREE ACCELERATION	Normal	Normal	Normal	
DRIVABILITY	Normal	Normal	Normal	

Comment: Pass.

VEHICLE: M3B	TEST TECHNICIAN Ezequias Borges de Menezes			
FUEL	CO68/2014 E-25%	C070 / 2014 E-27.5%	C072/2014 E-30%	NOTE
DATE	22/9/2014	22/9/2014	23/9/2014	
ATTEMPTS	2 attempts	3 attempts	4 attempts	
START-UP	Normal	Normal	Normal	
IDLE SPEED	Normal	Normal	Normal	
FREE ACCELERATION	Normal	Normal	Normal	
DRIVABILITY	Normal	Normal	Normal	
DATE	23/9/2014	23/9/2014	23/9/2014	
ATTEMPTS	2 attempts	2 attempts	3 attempts	
START-UP	Normal	Normal	Normal	
IDLE SPEED	Normal	Normal	Normal	
FREE ACCELERATION	Normal	Normal	Normal	
DRIVABILITY	Normal	Normal	Normal	

Comment: Pass.

Final Comments: The cold start tests become critical as the ethanol content is raised to 30%, but, except for the PM1A motorcycle, the others met the functional requirements of cold start and cold engine drivability, so, for functional purposes, the three ethanol contents passed the test on a conditional basis.

In the case of the PM1A motorcycle, the probable cause of non-fulfillment of requirements with E-30 is because it had non-original parts, which, due to their adaptation, do not have a correct air / fuel mixture for the various operating conditions. such as starting, idling, constant speed / rotation and variable rotation speed (acceleration / deceleration) regimes.

MOTORCYCLE RE-ACCELERATION DRIVABILITY

Test Methodology

When the tests were conducted, the engine of the motorcycles was heated (to temperatures above 80°C) and, then, the speed was stabilized in the last gear, the accelerator was abruptly actuated to full throttle and the time to cover 200 meters in acceleration was recorded. The speeds established varied according to the engine capacity ("cc") of each motorcycle, as described below:

- 30 and 40 km/h for the M3A model;
- 40 and 50 Km/h for the PM1A, M1A and M2A models:
- 50 and 60 km/h for the M3B model.

At least 6 trips were completed in each direction of the track for each mentioned speed and, since the motorcycles were old, the tolerance of ± 0,4 seconds within the average measurements for each fuel was adopted as a criterion.
Before each test, the previous fuel was removed from the tank, feed system lines and carburetors. The motorcycles equipped with electronic injection were conditioned by reheating the engine at 80°C in a constant rotation at around 4000 rpm, to ensure recognition of the new fuel to be tested.

Each test consisted of the following evaluations:

- Measurement of the time taken to travel 200 meters from the re-acceleration point for each speed/model;
- Monitoring of engine operation, checking for faults or abnormal engine operation during re-accelerations.

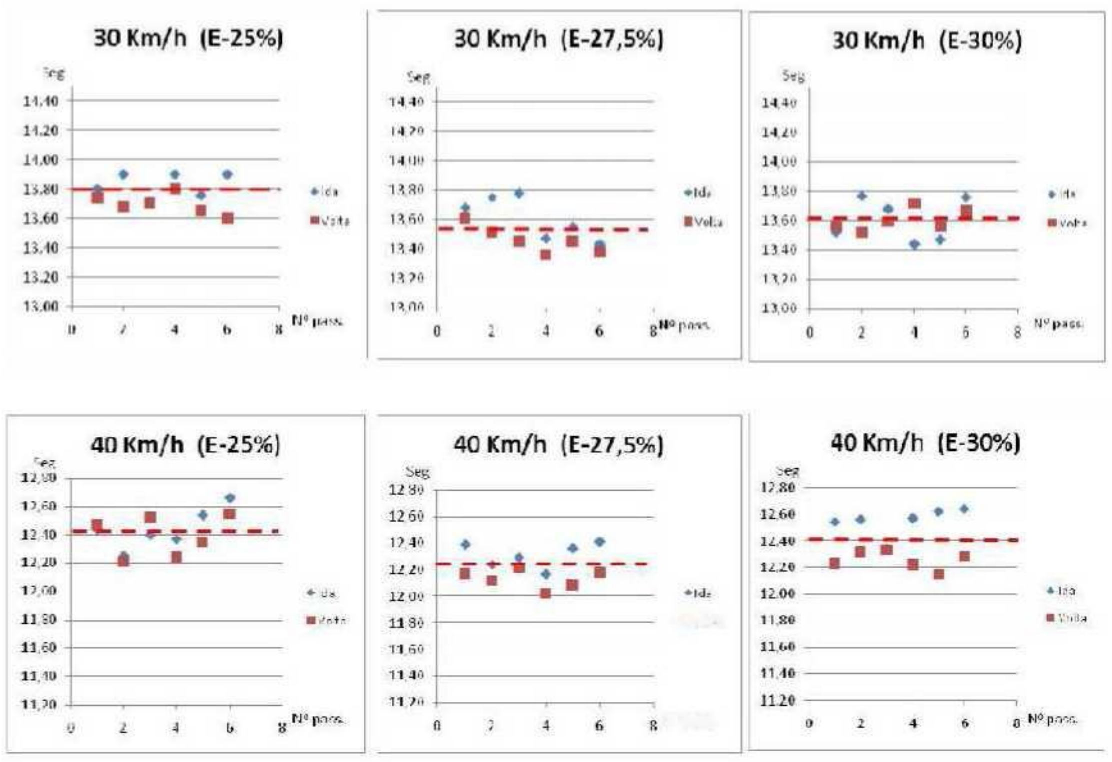
BR

Results and Discussion

Motorcycle M3A

RECOVERY		A 25%				A 27.5%				A 30%			
At 30 Km/h		km/h	(S)	Mean	Std Dev	km/h	(S)	Mean	Std Dev	km/h	(5)	Mean	Std Dev
TRIP TO THE END F THE TRAC K	0-200 m	30.6	13.80			30.6	13.68			30.7	13.52		
		30.6	13.90			30.7	13.75			30.3	13.77		
		30.4	13.70			30.9	13 78			30.9	13 68		
		30.3	13.90			30.4	13.47			30.5	1344		
		30.8	13,76			30.4	13.55			30.9	13.47		
		30.5	13.90			30.7	13.43			30.7	13.76		
TRIP BACK	0-200 m	30.6	13.74	13.76	0.101	30.1	13.61	13.54	0.141	30.9	1223	13.61	0.112
		30.5	13.68			30.5	13 52			30.8	12.32		
		30.3	13.71			30.3	13.45			30.7	12.33		
		30.0	13.80			30.5	13 36			30.8	12.22		
		30.3	13.65			30.5	13,45			30.6	12.15		
		30 4	13.60			30.7	13.38			30.9	12.29		

RECOVERY		A 25%				A 27.5%				A 30%			
At 40 Km Ti		km/h	(s)	Mean	Std Dev	km/h	(S)	Mean	Std Dev	km/h	(s)	Mean	Std Dev
TRIP TO THE END OF THE TRAC K	0-200 m	40.1	12.44			40.2	12 39			40 9	12.54		
		40.5	12.25			40.6	12.24			41.0	12 56		
		40.9	12.40			40.3	12.29			406	12.34		
		40.5	12.37			40.4	12.17			40.6	12.57		
		40.19	12.54			40.6	12.36			40.3	12.62		
		40.57	12.66			40,5	1241			40.2	12.64		
TRIP BACK	0-200 m	40.2	12.47	12.42	0.139	40.1	12.17	12.22	0.122	40.9	12.23	12.40	0.173
		40.5	12.21			40.6	12 12			409	12 32		
		40.2	12.52			40.7	12.22			40.5	12.33		
		40.5	12.25			40.7	12.02			40.3	12.22		
		40.2	12.35			40.6	12.09			406	12.15		
		40.6	12.55			40.7	12 18			40.6	12.29		



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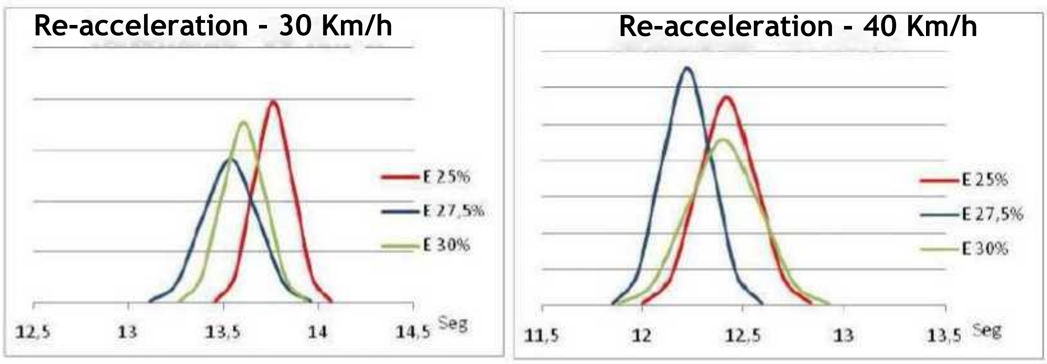
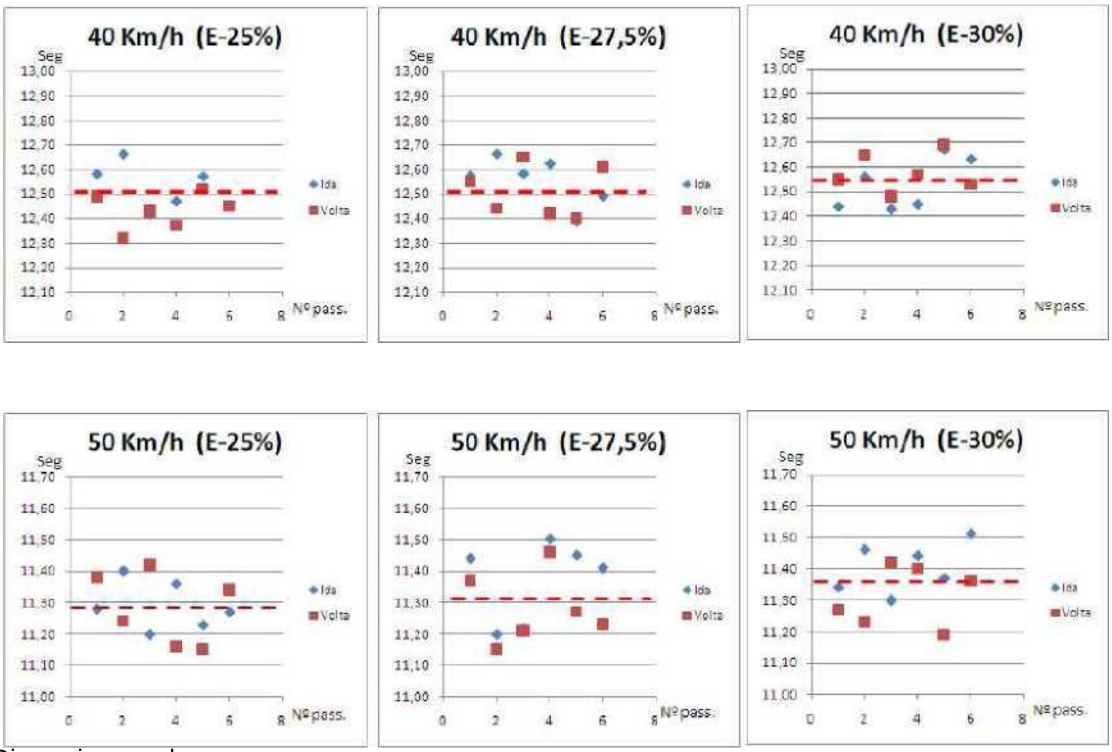


Comments: During the tests, the evaluator did not find any significant faults, choking or loss of performance among the 3 proportions of Ethanol content, so, it was considered that the motorcycle passed the drivability test.
The average time variation between the passes for each fuel is less than 0.4 seconds and was considered acceptable for the conditions of use of motorcycles and other variables such as wind, upward slope or downward slope, where we did not identify that the difference in the ethanol content had influenced the results. Therefore, the motorcycle passed the test.

Motorcycle M2A

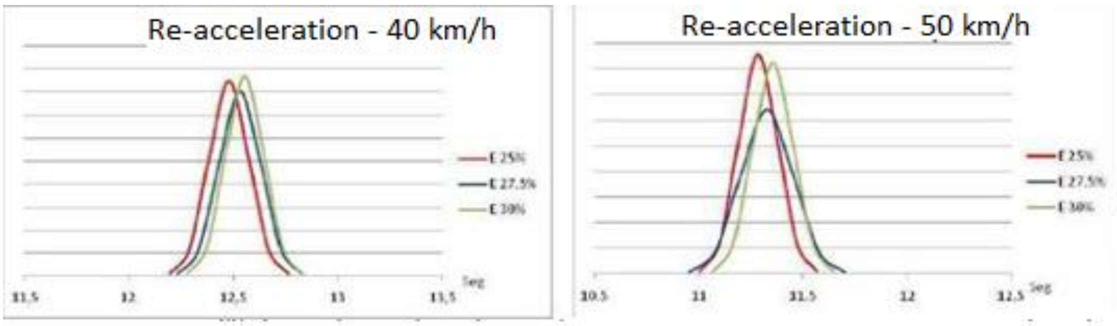
Reacceleration at 30 Km/h		A 25%				A 27,5%				A 30%			
		km/h	(s)	Average	Std Dev	km/h	(s)	Average	Std Dev	km/h	(s)	Average	Std Dev
TRIP TO THE END OF THE TRACK	0-200 m	40,7	12,58	12.48	0.094	40,5	12,57	12,53	0,099	40,4	12,44	12,55	0,092
		40,5	12,66			40,5	12,66			40,7	12,56		
		40,5	12,42			40,6	12,58			40,2	12,43		
		40,59	12,47			40,5	12,62			40,6	12,45		
		40,51	12,57			40,5	12,39			40,5	12,67		
		40,56	12,45			40,7	12,49			40,6	12,63		
TRIP BACK	0-200 m	40,9	12,49			40,5	12,55			40,5	11,27		
		40,2	12,32			40,5	12,44			40,5	11,23		
		40,2	12,43			40,8	12,65			40,2	11,42		
		40,8	12,37			40,5	12,42			40,3	11,40		
		40,9	12,52			40,9	12,40			40,5	11,19		
		40,4	12,45			40,9	12,61			40,6	11,36		

Re-acceleration At 40 km/h		A 25%				A 27,5%				A 30%		
		km/h	(s)	Mean	Std Dev	km/h	(s)	Mean	Desv Pd	km/h	(s)	Mean
TRIP TO THE END OF THE TRACK	0-200 m	50,3	11,28	11,29	0,093	50,4	11,44	11,33	0,124	50,4	11,34	11,36
		50,8	11,40			50,1	11,20			50,4	11,46	
		50,5	11,20			50,8	11,22			50,4	11,30	
		50,39	11,36			50,1	11,50			50,1	11,44	
		50,54	11,23			50,4	11,45			50,4	11,37	
		50,31	11,27			50,5	11,41			50,3	11,51	
TRIP BACK	0-200 m	50,6	11,38			50,5	11,37			50,5	11,27	
		50,5	11,24			50,3	11,15			50,9	11,23	
		59,2	11,42			50,6	11,21			50,5	11,42	
		50,4	11,16			50,2	11,46			50,6	11,40	
		50,5	11,15			50,5	11,27			50,3	11,19	
		50,3	11,34			50,4	11,23			50,4	11,36	



Dispersion graphs

Distribution



Comments: During the tests, the evaluator did not find any significant faults, choking or loss of performance among the 3 proportions of Ethanol content, so, it was considered that the motorcycle passed the drivability test.

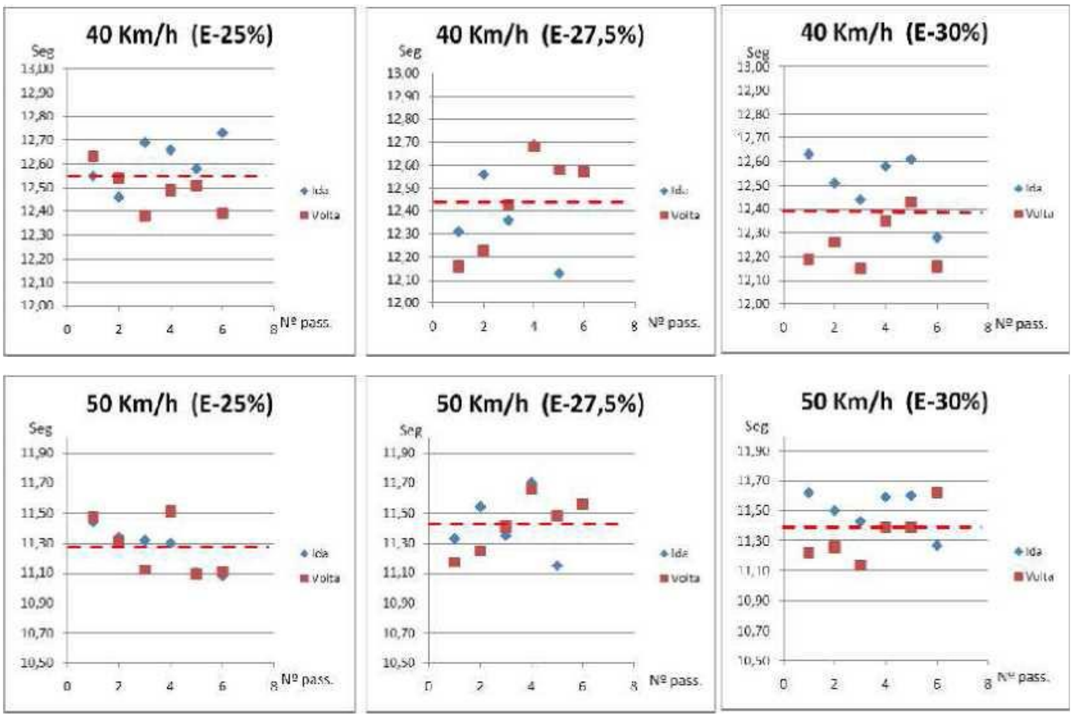
The average time variation between the passes for each fuel is less than 0.4 seconds and was considered acceptable for the conditions of use of motorcycles and other variables such as wind, upward slope or downward slope, where we did not identify that the difference in the ethanol content had influenced the results. Therefore, the motorcycle passed the test.

Motorcycle M1A

RE-ACCELERATION At 30 Km/h		A 25%				A 27.5%				A 30%			
		km/h	(s)	Mean	Std Dev	km/h	(s)	Mean	Std Dev	km/h	(s)	Mean	Std Dev
TRIP TO THE END OF THE TRAC	0-200 m	40.5	12.55			40.6	12.31			40 5	12 63		
		40.1	12.46			40.7	12.56			40 8	12 51		
		40.9	12.69			40.6	12.36			40 6	12 44		
		40 03	12.66			40.7	12.69			40 5	12 58		
		41 21	12.58			40.7	12.13			40 7	12 61		
		40 53	12.73			40.6	12.58			40 6	12 28		
TRIP BACK	0-200 m	40 1	12.63	12.55	0.113	40.7	12.16	12.44	0.198	40 9	11 22	12,38	0,176
		40 5	12.54			40.9	12.23			40 6	1126		
		40 5	12.38			40.6	12.43			40 8	11 14		
		40 2	12.49			40.6	12.68			40 5	11 39		
		40 6	12.51			40.9	12.58			40 5	11 39		
		40 6	12.39			40.2	12.57			40 5	11 62		

RE-ACCELERATION At 40 Km/h		A 25%				A 27.5%				A 30%			
		km/h	(s)	Mean	Std Dev	km/h	(s)	Mean	Std Dev	km/h	(s)	Mean	Std Dev
TRIP TO THE END OF THE TRACK	0-200 m	50 5	11 44			50 3	11 33			50 4	11 62		
		50 4	11 34			50 4	11 54			50 9	11 50		
		50 5	11 32			50 5	11 35			50 9	1143		
		50 51	11 30			50 8	11 70			50 2	11 59		
		505	11 10			50 5	11 15			50 5	11 60		
		50 48	11 08			50 5	11 56			50 8	11 27		
TRIP BACK	0-200 m	50 5	11 47	11.27	0.160	504	11 17	11.43	0.183	50 4	11 22	11.42	0,170
		502	11 31			50 5	11 25			50 5	11 26		
		50 3	11 12			50 4	1141			50 6	11 14		
		50 5	11,51			504	11 66			50 8	11 39		
		50 5	11 09			504	1148			50 9	11 39		
		505	11 11			50 7	11 56			50 5	11 62		

Distribution graphs



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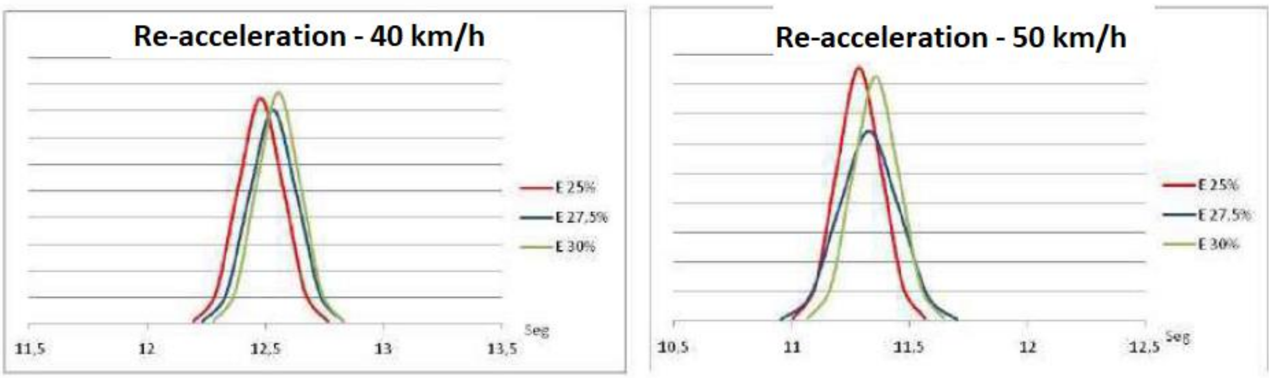


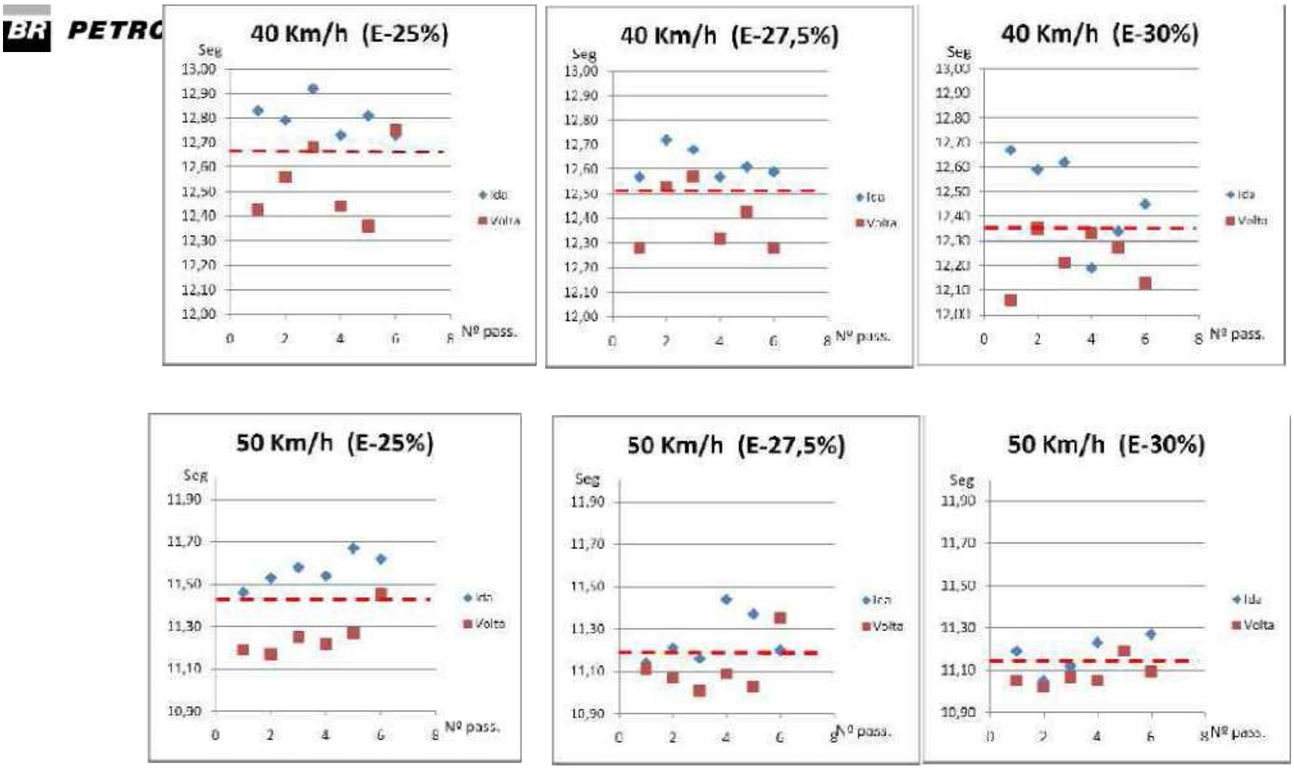
Comments: During the tests, the evaluator did not find any significant faults, choking or loss of performance among the 3 proportions of Ethanol content, so, it was considered that the motorcycle passed the drivability test.

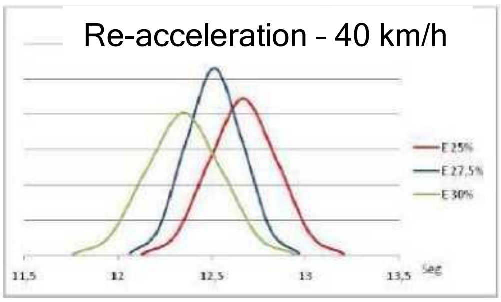
The average time variation between the passes for each fuel showed a higher dispersion for the E27.5 fuel, but it was clearly caused by lateral wind gusts (as reported by the evaluator). However, if we evaluate the general average of the graphs, it is still possible to conclude that the difference between the fuels remains very small (less than 0.4 seconds) and was considered acceptable for the conditions of use of the motorcycles. Therefore, it passed the test.

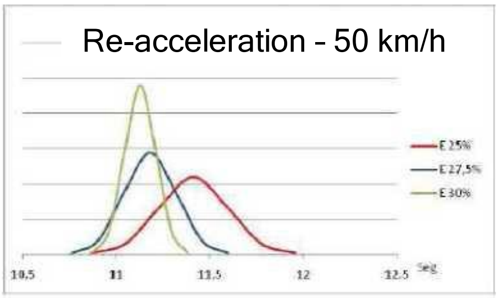
Motorcycle PM1A

Re-accelearte At 30 km/h		A 25% km/h	(s)	Mean	Std Dev	A 27.5% km/h	(s)	Mean	Std Dev	A 30% km/h	(s)	Mean	Std Dev
TRIP TO	0-200 m	40,3	12 83			402	12 57			40.9	12 67		
		40,9	12 79			40 3	12 72			40 5	12 59		
		40 5	12 92			40 6	12 68			40.7	12 62		
		40 56	12 73			40 46	1257			40 9	12 19		
		40.39	12 81			40 1	12 61			40.6	12.34		
		40 35	12 73			40 5	12 59			40 4	12 45		
TRIP BACK	0-200 m	40 6	12 43	12,67	0,180	40 4	12 28	12.51	0,150	40 4	11 05	12.35	0,197
		40 6	12 56			40 7	12 53			40.7	11 02		
		40 6	12 68			40 7	12 57			406	11 07		
		40.5	12 44			40 6	12 32			40.5	11 05		
		40 4	12 36			404	12 43			40 4	11 19		
		406	12 75			40 0	12 28			40 9	11 09		

Re-accelearte At 40 km/h		A 25% km/h	(S)	Mean	Std Dev	A 27.5% km/h	(Sj	Mean	Std Dev	A 30% km/h	(S)	Mean	Std Dev
Trip to	0-200 m	50 4	1146			50 5	11 14			50 9	11 19		
		50 5	11.53			50 3	11.21			50 8	11 05		
		50 0	11 58			50 8	11 16			50 5	11 12		
		50 75	11 54			50 6	11 44			50 3	11 23		
		50 54	11 67			50 5	11 37			50 9	11 19		
		50.54	11 62			50 2	11 20			50 4	11.27		
Trip back	0-200 m	50 5	11 19	11,41	0,182	50.2	11 11	11,18	0,139	50.1	11 05	11,13	0,084
		50 0	11 17			50 2	11 07			50 5	11 02		
		504	1125			50 3	11 01			50 6	11 07		
		50 8	11 22			50 6	11 09			50.2	11 05		
		50 5	11 27			50 2	11 03			50 6	11 19		
		50.5	1145			504	11 35			50.9	11 09		







Comments: During the tests, the evaluator identified small faults and chokings, but they were basically equal in the three proportions of Ethanol content, ie, no difference in functional sensitivity was observed among the three levels of Ethanol.

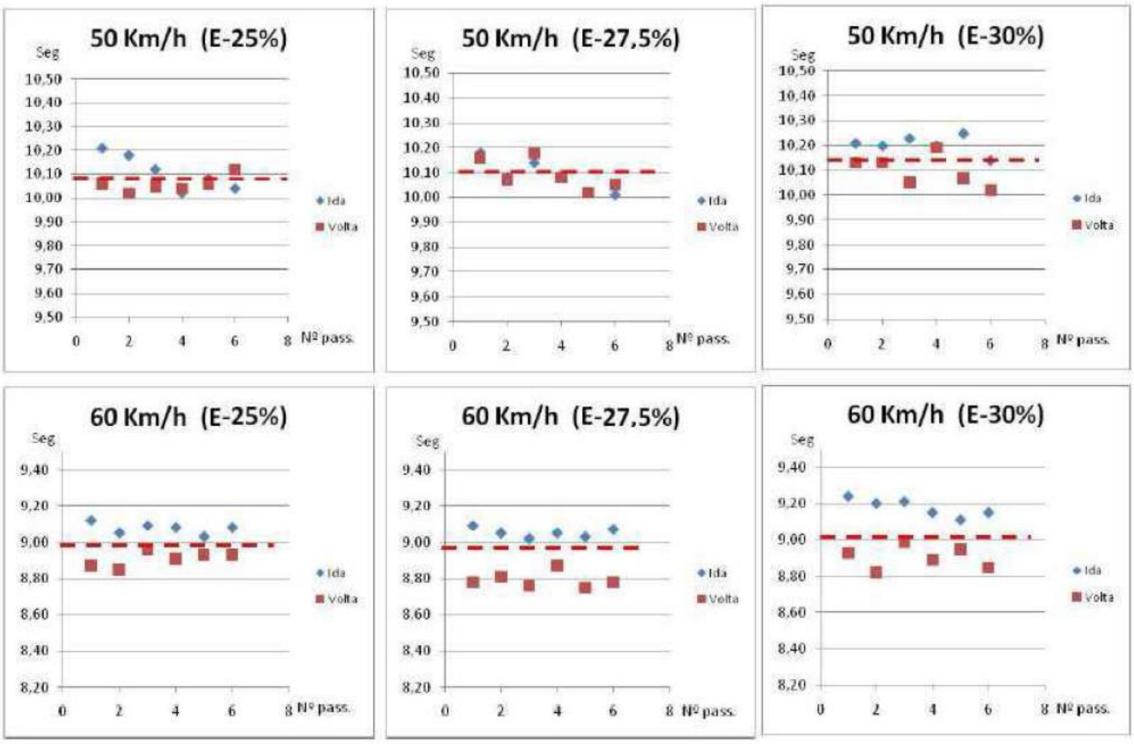
In the dispersion re-acceleration (speed recovery) graphs, it is possible to notice a gain in the times (around 0.3 sec) as the alcohol content increases. The probable cause may be the fact that the carburetor of this motorcycle is not original and also because it is a copy of an older version of this model, equipped with a fuel injector where the air / fuel mixture can be richer with E-25% and more adequate/poorer with E-30%, thus showing improvement in the results because that ethanol impoverishes the blend.

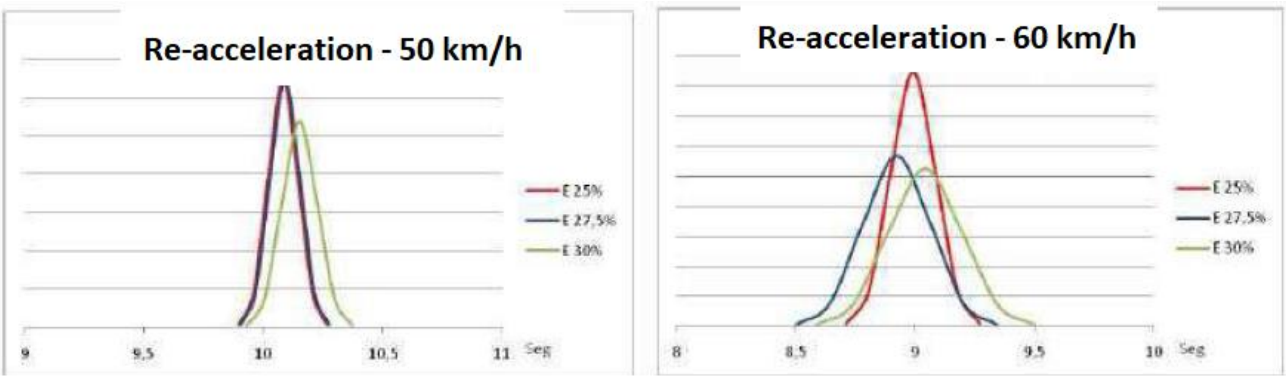
The variation in the average time between the passes for each fuel remains below 0.4 sec. However, the results are acceptable, because, in this motorcycle, with non-original parts, we found the greatest variation among the five models tested. It is important to note that motorcycles, with this type of modification, may present functional problems and even durability problems, if the air/fuel mixture of the adapted part is poorer than what this motorcycle had.

Motorcycle M3B

Re-accelerate At 30 Kmti		**A 25%** krrVh	(S)	Mean	Std Dev	**A 27.5%** krrVh	(S)	Mean	Std Dev	**A 30%** km/h	(S)	Mean	Std Dev
Trip to the end of the track	0-200 m	50.6	10.21			50.9	10.18			50.5	10.21		
		50.2	10.18			50 8	10.08			50.1	10.20		
		506	10.12			50 5	10.14			50.3	1023		
		50.54	10 02			50.1	10.09			50.4	10.20		
		50.03	10.08			50.5	10.02			50 4	10.25		
		50.45	10.04	**10.08**	0.062	50.6	10.01	10,09	0.062	50.4	10.14	**10.15**	**0.074**
Trip back	0-200 m	50.4	10.06			50.6	10.16			50.5	8.93		
		50.1	10.02			50.8	10.07			50 5	8 82		
		50.2	10.05			50 8	10.18			50.9	8.99		
		50.2	10.04			50.4	10.13 8			50.5	8.89		
		50.3	10 06			50 8	10.02			50.8	8 95		
		50.3	10.12			50.4	10.05			50.5	8.85		

Re-accelerate at 40 km/h		**A 25%** krrVh	<3)	Mean	Std Dev	**A 27.5%** kmh	(9)	Mean	Std Dev	**A 30%** krrvh	(S)	Mean	Std Dev
TRIP TO THE END OF THE TRACK	0-200 m	60.5	9 12			60.2	9.09			60.8	9.24		
		60.6	9.05			60 7	905			60.8	9.20		
		60.8	9.09			60.8	9.02			60.7	9.21		
		60.41	9.08			60.5	9.05			60 8	9.15		
		60,78	9,03			60 4	9.03			60.7	9.11		
		60.56	9.08	8.99	0.094	60.5	9.07	8.92	0,140	60.8	9,15	9.04	0.152
TRIP BACK	0-200 m	60.4	8.87			60.8	8.78			60.1	8.93		
		60.7	8.85			60.8	8.81			60.8	8.82		
		60.7	8.96			60.6	8.76			60.7	8.99		
		60.4	8.91			60.7	8.87			60.8	8.89		
		60.8	8.93			60.7	8.75			60.6	8.95		
		60.6	8.93			60.9	8.78			60.7	8.35		





Comments: During the tests, the evaluator did not find any significant faults, choking or loss of performance among the 3 proportions of Ethanol content, so, it was considered that the motorcycle passed the drivability test.

The average time variation between the passes (divided into departure and return) for each fuel is less than 0.4 seconds and was considered acceptable for the conditions of use of motorcycles and other variables such as wind, upward slope or downward slope, where we did not identify that the difference in the ethanol content had influenced the results. Therefore, the motorcycle passed the test.

Final Comments: From the point of view of drivability, re-acceleration (speed recovery) and cold start, we consider the use of the E-27.5% content to be viable. However, the tests using motorcycles with non-original parts drew attention to the risk of presenting not only functional problems (such as those detected in these tests with E-30%), but also problems related to durability, since these parts do not follow the factory standards and may cause damages to the product, if used with high levels of ethanol in the gasoline.