PETROBRAS

EFFECTS OF E27.5 AND E30 ON YAMAHA MOTORCYCLES

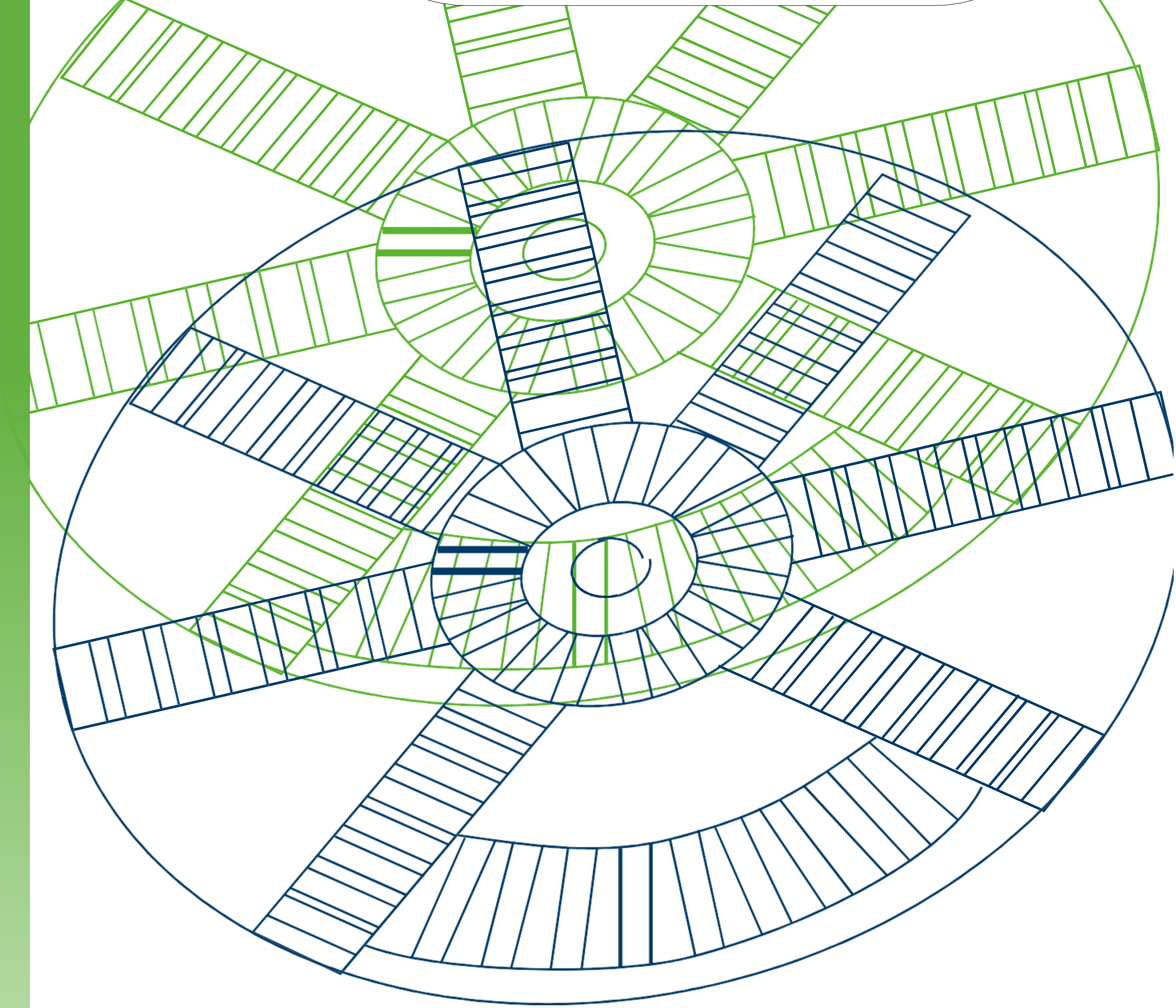
RT DPM 020/14

Technical Report

SUPPLY R&D

Performance of Products in Engines

December 2014



CENPES

Centro de Pesquisas e Desenvolvimento

Leopoldo A. Miguez de Mello

PETROBRAS

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[RESEARCH AND DEVELOPMENT CENTER LEOPOLDO A. MIGUEZ DE MELLO]
SUPPLY AND BIOFUELS R & D
Performance of Products in Engines

EFFECTS OF E27.5 AND E30 ON YAMAHA MOTORCYCLES

RT DPM 020/14

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SUMMARY

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

The initial stage of the study consisted of tests carried out in 8 vehicles and 5 motorcycles, for evaluations of pollutant emissions, re-acceleration ("speed recoveries"), cold start, cold engine drivability and fuel consumption, as well as engine performance tests and analysis of lubricity and gum of the blends.

Later, as agreed in the working group coordinated by the MME, additional performance tests (cold start, cold engine drivability and speed recovery) were carried out on the test track of CAEx (Army Evaluation Center) in four vehicles provided by ANFAVEA. Three of these vehicles had different fuel injection technologies that addressed the L5 and L6 phases, and a hybrid vehicle that addressed the L5 phase of PROCONVE (Air Pollution Control Program for Automotive Vehicles).

In addition, MME asked PETROBRAS to evaluate the performance of the same fuels with 27.5 and 30% v/v ethanol content, denominated E27.5 and E30, with respect to emissions and fuel economy, in Yamaha motorcycles. In view of the fact that in the matrix of tests performed in the first step, the motorcycles of this manufacturer were not available for the study. This is the scope of this report.

In the tests, the ethanol contents of 22, 25, 27.5 and 30% v/v added to the emissions standard A gasoline. These fuels were called E22, E25, E27.5 and E30, and the gasoline E22 was established a reference for these tests.

In the two motorcycles that were tested, there was a general trend towards the reduction in THC and CO emissions, which accompanied the increase in ethanol content between the levels of 22% v/v and 30% v/v. However, it was found that there was a trend towards an increase in NOx emission, but the PROMOT limit for this pollutant was not reached. With respect to CO2, there was a reduction in one motorcycle and an indefinite trend in the other. In terms of fuel economy, there was an improvement with the increase of the ethanol content, explained by the fact that the motorcycles were carbureted and regulated with a mixture that was richer than the stoichiometric one.

In the comparison between the results obtained with E27.5 and E25, there were reductions of up to 10% in THC, 36% in CO, 2% in CO_2 and an improvement of up 2% in fuel economy, in addition to an elevation of up to 32% in NO_x.

Finally, it should be emphasized that the possible effects of the new ethanol contents on the durability of components were not part of the scope of this study.

1. INTRODUCTION

This study is a response to a request made by the Ministry of Mines and Energy (MME), which asked PETROBRAS to assess the possible effects of greater ethanol contents (in the mixture with gasoline) on the performance of gasoline powered vehicles.

The request was submitted to CENPES, which prepared a work plan that comprised, as a first step, the evaluation of the gasoline-ethanol blends with 22, 25, 27.5 and 30% v/v ethanol in terms of emissions, consumption and performance (cold start, cold engine drivability and re-acceleration) in 8 vehicles and 5 motorcycles, test bench engine performance, and analytical tests of lubricity and gum of the blends. These results were reported in RT DPM 008/14(1).

During the meetings of the ANFAVEA, ABRACICLO, ABEIFA, UNICA, INMETRO, INT, LACTEC, PETROBRAS, MDIC and MME group, which were coordinated by the latter, ANFAVEA requested the assessment of the track performance of 4 additional vehicles provided by the automakers, and these additional tests were monitored by professionals of the respective participating companies. These results were reported in RT DPM 010/14 (2).

Subsequently, PETROBRAS received a new request from MME to carry out additional emission and fuel economy tests with Yamaha motorcycles, because the Yamaha company had asked for its models to be included in a new round of tests, since they had not been tested in the initial phase of the program.

The tests were carried out from October to November 2014, at the LACTEC Institute's Emissions Laboratory in Curitiba, Paraná, and the results and conclusions of this study are incorporated in 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 of standard A gasoline and 22% v/v of ethanol;
- Gasoline **E25**: formulated with 75% v/v of standard A gasoline and 25% v/v of ethanol;
- Gasoline **E27.5**: formulated with 72.5% v/v of standard A gasoline and 27.5% v/v of ethanol;
- Gasoline **E30**: formulated with 70% v/v of standard A gasoline and 30% v/v of ethanol.

The specifications of the standard A gasoline and ethanol for carrying out pollutant emission and fuel economy tests are defined, respectively, by ANP resolutions number 5 (3) and number 6 (4), of February 24, 2005.

The physicochemical analyses of the fuels used can be found in Annex I to this report.

3. MOTORCYCLES USED

In the selection of motorcycles, we tried to use the same models used by the manufacturer in its internal tests, with accumulated mileage compatible with the year of manufacture of each one, and in good condition, that is, those that did not have drivability problems or did not exceed the emission limits of the vehicle inspection and maintenance programs established in CONAMA Resolution 297/2002, whether or not they met the respective approval limits of PROMOT.

Therefore, the motorcycles did not undergo any type of special repair prior to testing. The intention was to ensure that the sample tested would reflect more realistically the condition of motorcycles that are currently being used in the market. Table I describes the main characteristics of the selected motorcycles:

Table I - Main characteristics of the motorcycles

Motorcycle Code	PROMOT Phase	Year	Odometer Reading (km)	CC	Powering System
M3C	M3	2011	13850	115	Carburetor
M3D	M3	2011	11279	125	Carburetor

4. EMISSION AND FUEL ECONOMY TESTS

4.1. 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 (5), in which the test vehicle is subjected to a controlled load condition on a chassis dynamometer (figure1).

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 2). The gases measured in this test are total hydrocarbons (THC), carbon monoxide (CO), carbon dioxide (CO2) and nitrogen oxides (NOx). The analytical techniques for determining these gases are the same as those used in light vehicle tests.

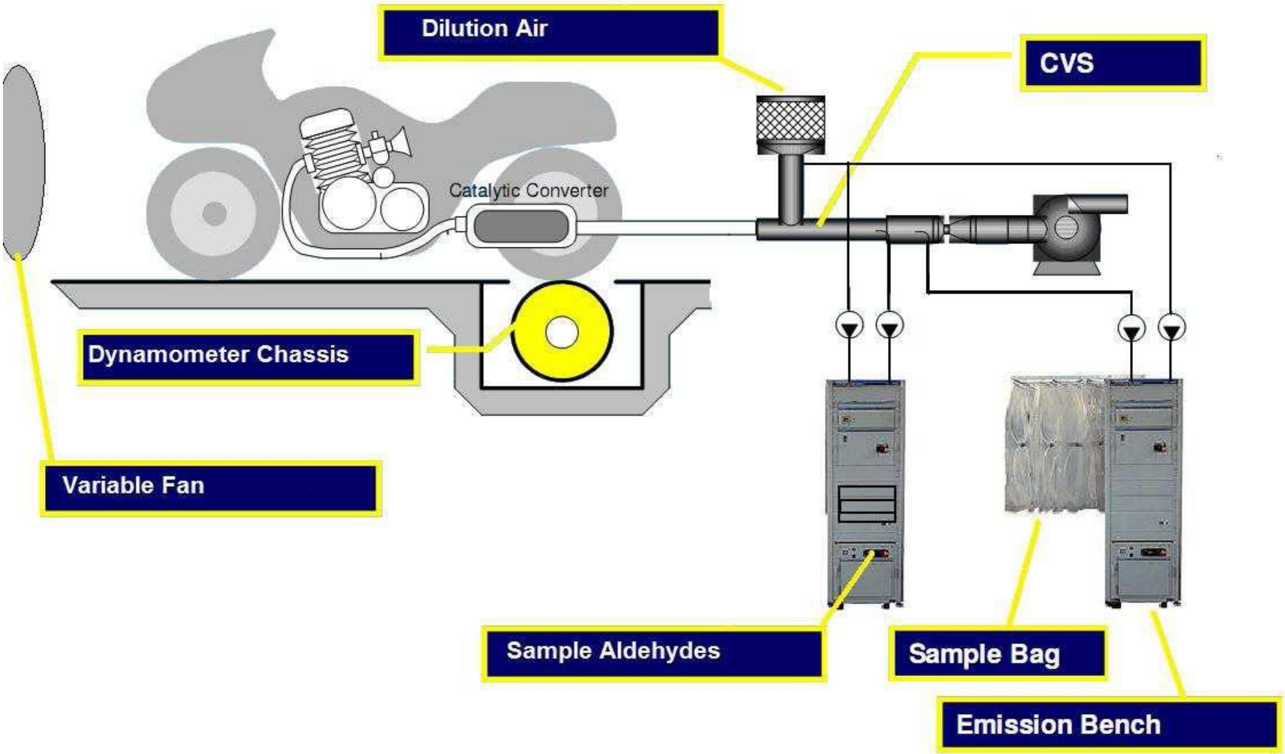


Figure 2 - Scheme of sample collection for the test of emissions in motorcycles.

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. 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 motorcycle, in order to verify in which cases 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 $p \leq 0.05$.

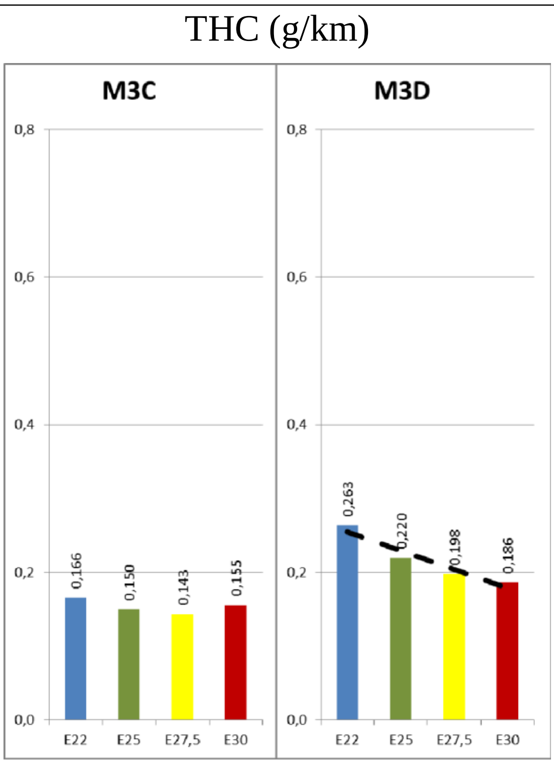
In the Regression Analysis, the data are statistically treated in order to verify the existence of a functional relationship between a dependent variable and one or more independent variables. With the resulting equation, we try to better understand the phenomenon that relates the variables, in order to observe behavior trends and estimate results (6). The graphs resulting from the Regression Analysis that was performed are listed in Annex II.

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. ").

4.3. Results and Discussion

Figures 3 to 7 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.

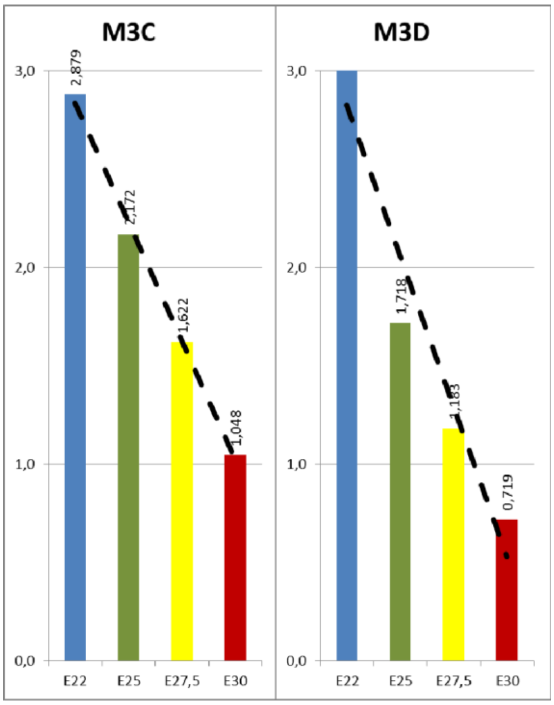
Annex II shows graphs with the experimental points, regression lines and curves of the error inherent in the fit. In the same annex, there is a table with the values of the regression coefficients, as well as the estimated values for points E22, E25, E27.5 and their respective confidence intervals.



Notes: 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 3 - THC emissions in the motorcycles.

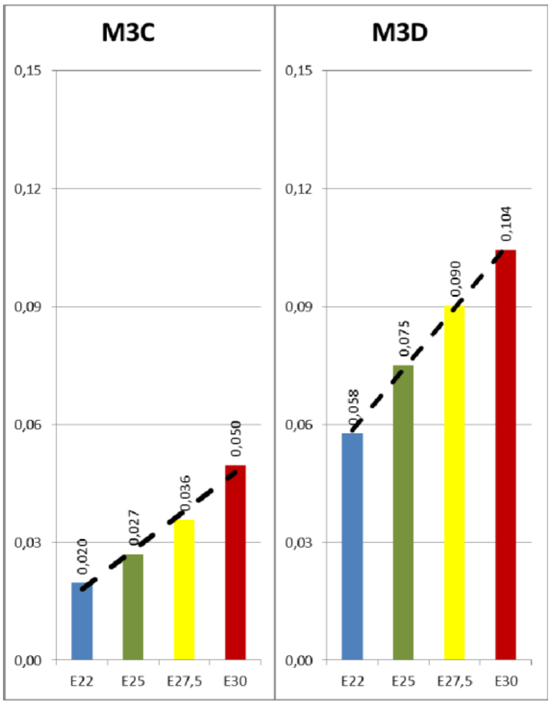
CO (g/km)



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

Figure 4 - CO emissions in the motorcycles.

NOx (g/km)



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

Figure 5 - NOx emissions in the motorcycles.

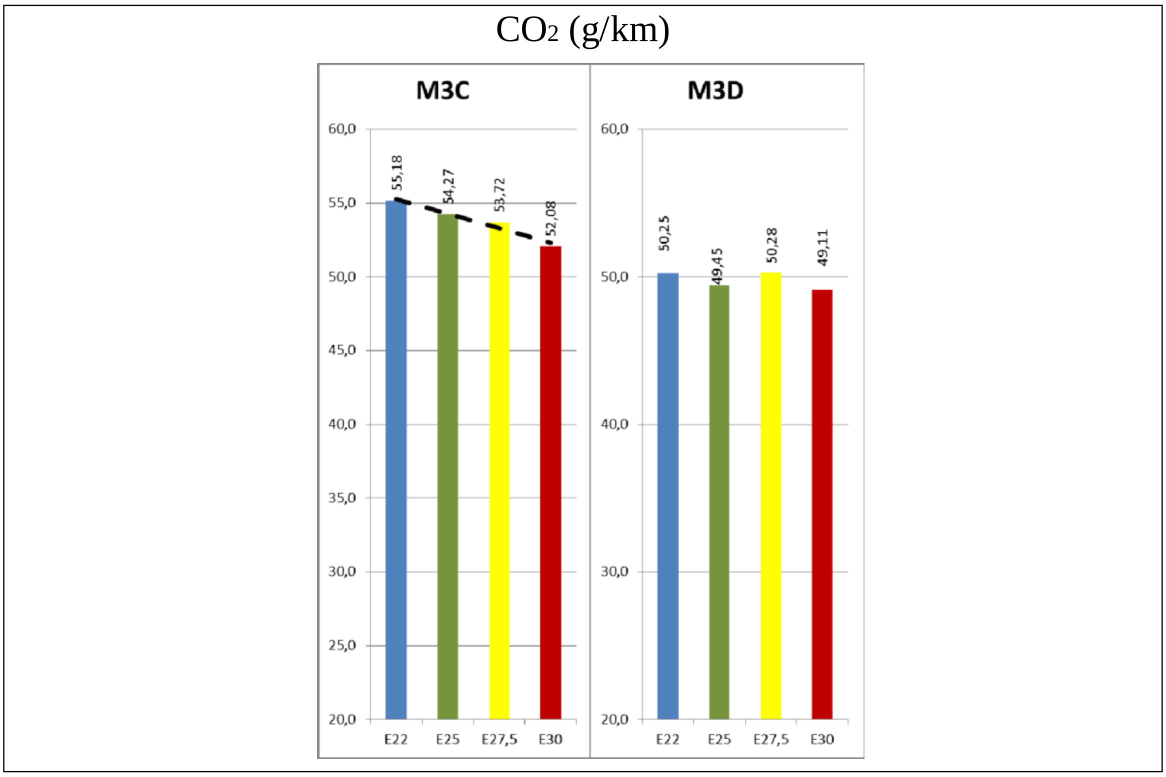


Figure 6 - CO_2 emissions in the motorcycles.

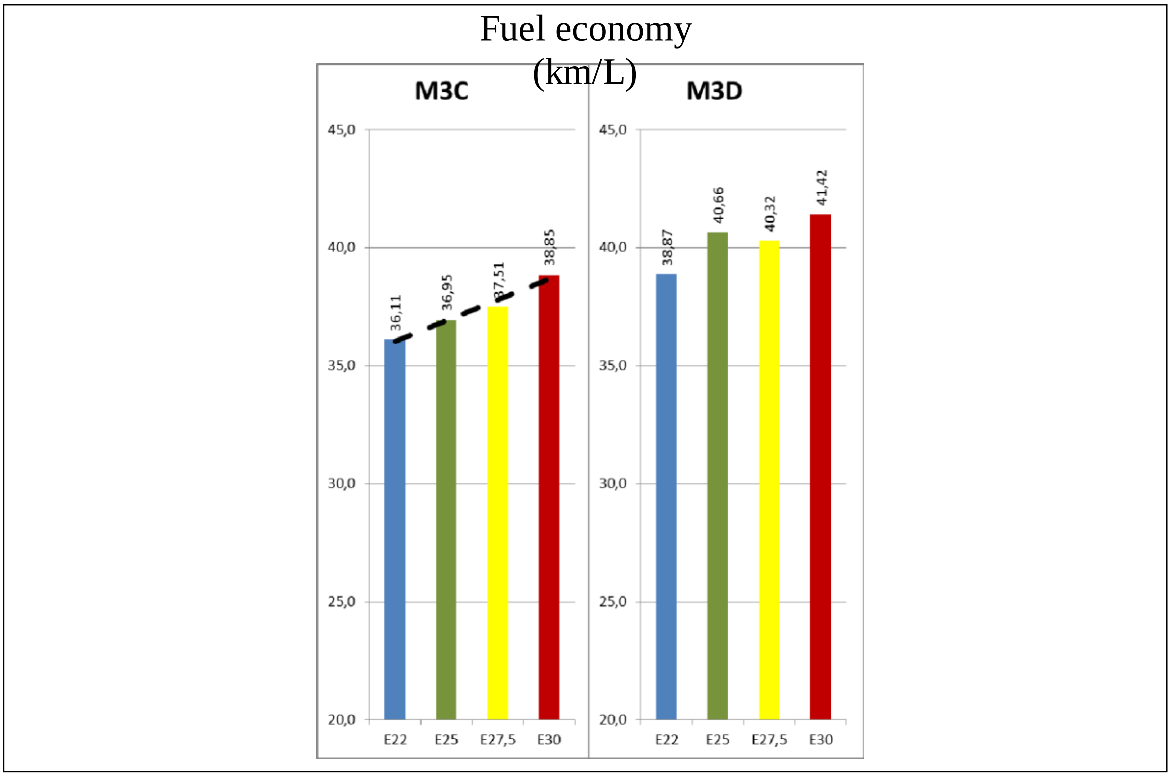


Figure 7 - Fuel economy in the motorcycles.

The mileage of the tested motorcycles was of less than 18,000 km and, therefore, their emissions were compared with the respective PROMOT limits. It was found that both met all the limits, except for CO. It should be noted that the motorcycles complied with the emission limits of vehicle inspection and maintenance and did not present functional anomalies.

There was a trend towards a reduction in THC, CO and CO2 emissions that accompanies the increase in the ethanol content.

It was found that there was a trend towards an increase in NOx emissions in the motorcycles. However, it should be noted that, for both motorcycles, the highest value found (M3D with E30) was still 24% below the value established by PROMOT.

With regard to fuel economy, there was improvement in both motorcycles. 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.

Comparison with E22

Tables II to IV show the comparison of the E25, E27.5 and E30 fuels 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 fuel economy. For better visualization, results that represent an improvement in the attribute are highlighted in green, while worse results are in red.

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

E27.5 x E22		
Motorcycles	M3C	M3D
THC	no diff.	-11%
CO	-24%	-30%
NOx	62%	30%
CO_2	-2%	no diff.
Fuel Economy	3%	2%

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

E27.5 x E22		
Motorcycles	M3C	M3D
THC	no diff.	-21%
CO	-44%	-56%
NOx	114%	55%
CO_2	-4%	no diff.
Fuel Economy	5%	4%

Table IV - Comparison between emissions and fuel economy with E30 and E22

E30 x E22		
Motorcycles	M3C	M3D
THC	no diff.	-30%
CO	-64%	-81%
NOx	165%	81%
CO_2	-5%	no diff.
Fuel Economy	7%	6%

In the comparison between the results obtained with E25 and E22 (Table II), it was found that there were reductions in the THC, CO and CO_2 emissions of 11%, 30% and 2%, respectively. However, there was an increase in NOx emission of up to 62%, and improved fuel economy by up to 3%.

With the use of the E27.5 and E30 fuels, there was an accentuation of the behaviors described above, as shown in Tables III and IV.

For the E22 reference, the use of E27.5 resulted in more marked reductions in THC and CO emissions (up to 21% and 56%, respectively), a more discrete reduction (up to 4%) in CO_2 and a more considerable increase in NOx emissions (up to 114%), which can be explained by the fact that motorcycles were set for richer mixtures. As the ethanol content was increased, the engines started operating in a more optimized manner and that even led to an increase in fuel economy by up to 5%.

With the E30 fuel, it is possible to notice that this behavior was accentuated, and the reductions in the THC, CO and CO_2 emissions were of up to 30%, 81% and 5%, respectively, and the increase in NOx emissions reached values of up to 165%. Fuel economy was further improved (up to 7%), confirming the richer setting of the air-fuel ratio.

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 (except for M3C), CO and CO_2 emissions and increase in NOx emissions and fuel economy (except for M3D), as shown in Tables V and VI.

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

E27.5 x E25		
Motorcycles	M3C	M3D
THC	no diff.	-10%
CO	-26%	-36%
NOx	32%	19%
CO_2	-2%	no diff.
Fuel Economy	2%	no diff.

Table VI - Comparison of emissions and fuel economy between E30 and E25

E30 x E25		
Motorcycles	M3C	M3D
THC	-5%	-21%
CO	-52%	-73%
NOx	64%	39%
CO_2	-3%	no diff.
Fuel Economy	4%	4%

5. COMPARISON WITH THE MANUFACTURER'S RESULTS

Table I below shows a comparison between the results obtained in the tests carried out by CENPES and those presented in the technical report submitted by Yamaha (Annex III)

Table I - Comparison of the E27.5 results with E25 of the tests carried out by CENPES and YAMAHA

	CENPES			YAMAHA		
HC	Comparison	M3C	M3D	Comparison	M3C	M3D
	E27,5 x E25	s/dif.	-10%	E27,5 x E25	s/dif.	-5%
CO	Comparison	M3C	M3D	Comparison	M3C	M3D
	E27,5 x E25	-26%	-36%	E27,5 x E25	-16%	-24%
NOx	Comparison	M3C	M3D	Comparison	M3C	M3D
	E27,5 x E25	32%	19%	E27,5 x E25	14%	16%
CO_2	Comparison	M3C	M3D	Comparison	M3C	M3D
	E27,5 x E25	-2%	s/dif	E27,5 x E25	-1%	-1%
Aut.	Comparação	M3C	M3D	Comparação	M3C	M3D
	E27,5 x E25	2%	s/dif	E27,5 x E25	1%	1%

6. CONCLUSIONS

This study evaluated the impact of the addition of the 27.5 and 30% v/v ethanol contents to gasoline, compared to the standard emission gasoline, used as reference, with 22% v/v ethanol content, in emission tests and "city" fuel economy tests.

In the tests carried out at CENPES, there was a significant reduction in THC, CO and CO_2emissions, which accompanied the increase in the ethanol content between the levels of 22% v/v and 30% v/v, and there was also an improvement in fuel economy. However, there was a significant increase in NOx emissions, although the PROMOT limit was not reached for this pollutant.

In the comparison between the results obtained with E27.5 and E25, there were reductions of up to 10% in THC, 36% in CO, 2% in CO_2 and an improvement of up 2% in fuel economy. With regard to NOx, there was an increase of up to 32%. It should be noted that, in these tests, the PROMOT limits were not reached at any time.

In the comparison of CENPES's results with those provided by the manufacturer, there was the same trend, although the values found were different. This difference could be explained by the fact that the rental motorcycles tested by CENPES were operating with a richer mix, which is why the increase in ethanol led to more favorable results.

In addition, it should be emphasized that the possible effects of the new ethanol contents on the durability of components were not part of the scope of this study. This shall be part of another study that should be carried out by the motorcycle manufacturers, represented by ABRACICLO.

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(2) PETROBRAS CENPES Technical Report, Effect of E27.5 and E30 on Gasoline Vehicles Provided by ANFAVEA, Technical Report DPM 010/14, November 2014 [Relatório Técnico PETROBRAS CENPES, Efeito do E27,5 e do E30 em Veículos a Gasolina Cedidos pela ANFAVEA, Relatório Técnico DPM 010/14, novembro de 2014];

(3) ANP (Agência Nacional do Petróleo, Gás Natural e Biocombustíveis = Brazilian Agency of Petroleum, Natural Gas and Biofuels), Resolution ANP number 5/2005, of February 2005;

(4) ANP (Agência Nacional do Petróleo, Gás Natural e Biocombustíveis = Brazilian Agency of Petroleum, Natural Gas and Biofuels), Resolution ANP number 6/2005, of February 2005;

(5) European Parliament, Directive 97/24/EC, 1997;

(6) ()) Montgomery D. C., George C. R.; Estatística Aplicada e Probabilidade para Engenheiros - LTC Editora, 2003 ("Applied Statistics and Probability for Engineers");

ANNEX I

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 D5453	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 D4052	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 D5191	54,8	56.5	58.2	56.7	56.2
Types of Hydrocarbons: Aromatic, %v Olefinic, %v 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 D4809	46.539	42.392	41.903	41.658	40.729
Lubricity	ASTM D6079	764	691	681	671	679

LII = Clear and free of impurities

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

Tests	Referenc e Methods	Limits (1)	2014-010347-38
Appearance	- Visual	LII	LII
Color	- Visual	(2)	orange
Total acidity, mg/L	NBR 9866	30 max.	14,4
Electrical conductivity, µS/m	NBR 10547	389 max.	103
Specific density at 20°C, kg/m3	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
Hydro-ethanol 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

ANNEX II

RESULTS OF EMISSIONS OF POLLUTANTS AND FUEL

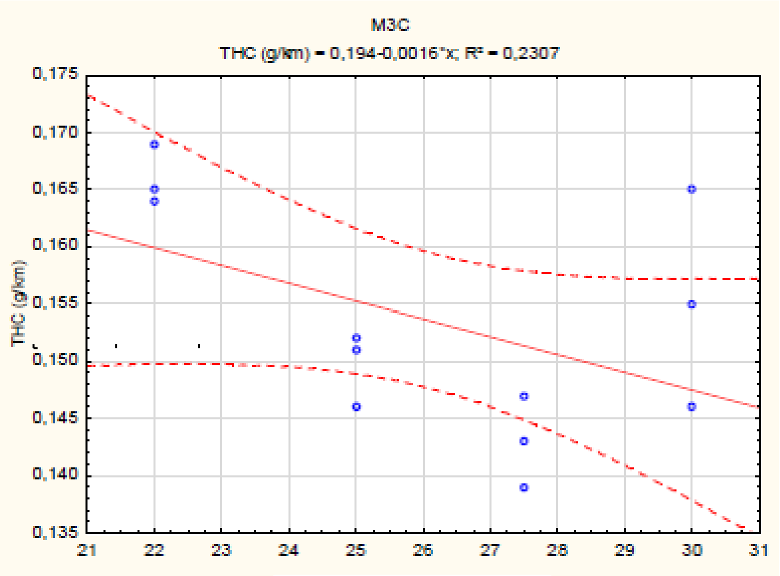
ECONOMY / CHARTS RESULTING FROM THE REGRESSION

ANALYSIS

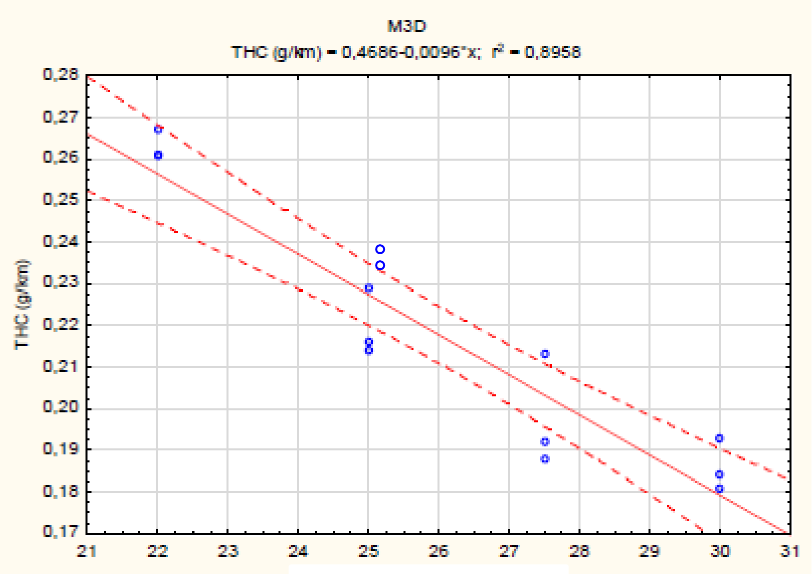
Results of emissions and fuel economy in motorcycles

Motorcycle	Ethanol Content (% v/v)	THC (g/km)	CO (g/km)	NOx (g/km)	CO_2 (g/km)	Fuel economy (km/L)
M3C	22	0.164	2.716	0.019	54.932	36.41
M3C	22	0.169	2.958	0.019	54.671	36.33
M3C	22	0.165	2.964	0.021	55.926	35.59
M3C	25	0.152	1.958	0.031	54.529	36.99
M3C	25	0,146	2,274	0,024	54,162	36,92
M3C	25	0,151	2,283	0,026	54,114	36,93
M3C	27,5	0,139	1,541	0,036	53,602	37,68
M3C	27,5	0,147	1,645	0,035	53,676	37,50
M3C	27,5	0,143	1,680	0,036	53,870	37,35
M3C	30	0,155	0,963	0,056	52,700	38,50
M3C	30	0,146	0,969	0,051	51,651	39,26
M3C	30	0,165	1,212	0,042	51,878	38,78
M3D	22	0.267	3.122	0.057	50.475	38.67
M3D	22	0.261	2.887	0.061	50.432	38.97
M3D	22	0.261	3.259	0.055	49.844	38.97
M3D	25	0.216	1.664	0.074	49.369	40.80
M3D	25	0.229	1.908	0.072	49.154	40.64
M3D	25	0.214	1.581	0.079	49.822	40.55
M3D	27.5	0.213	1.273	0.092	50.508	40.00
M3D	27.5	0.188	1.168	0.091	50.548	40.15
M3D	27.5	0.192	1.107	0.088	49.797	40.80
M3D	30	0.184	0.688	0.110	49.067	41.51
M3D	30	0.193	0.798	0.098	49.062	41.33
M3D	30	0.181	0.671	0.105	49.208	41.43

THC

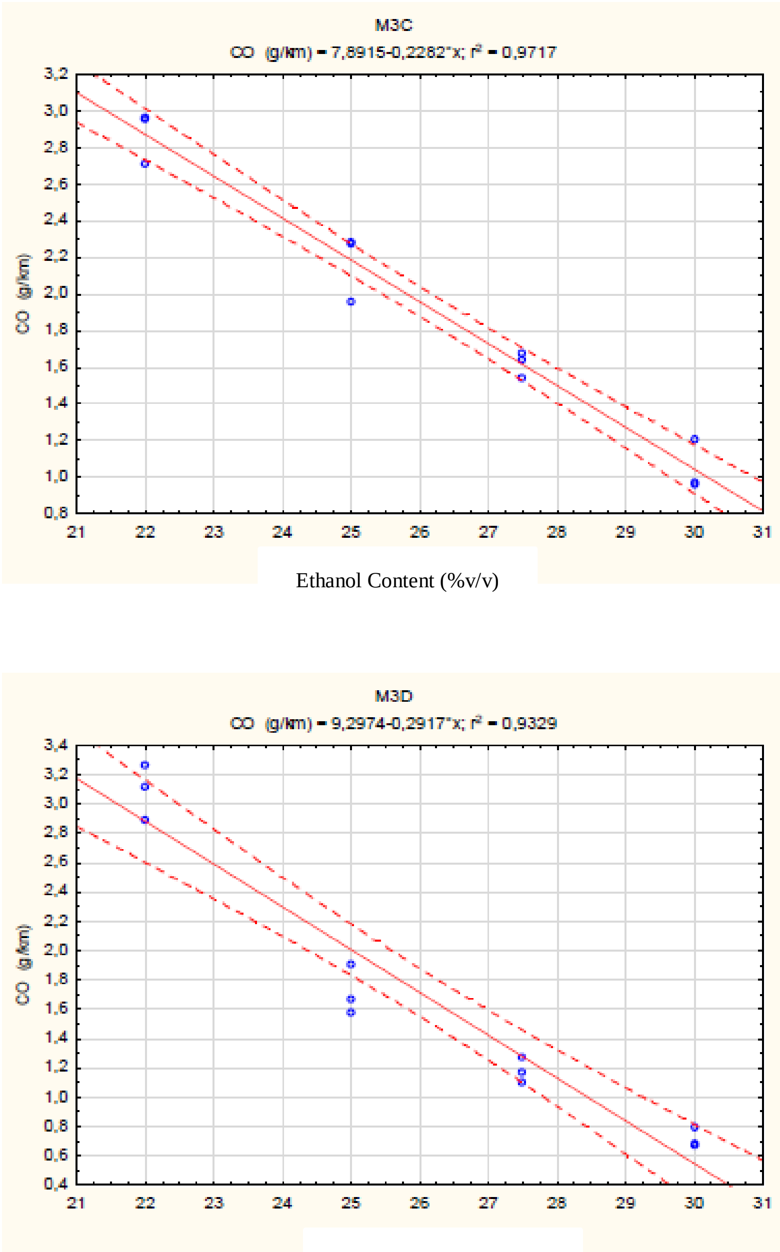


Ethanol Content (%v/v)

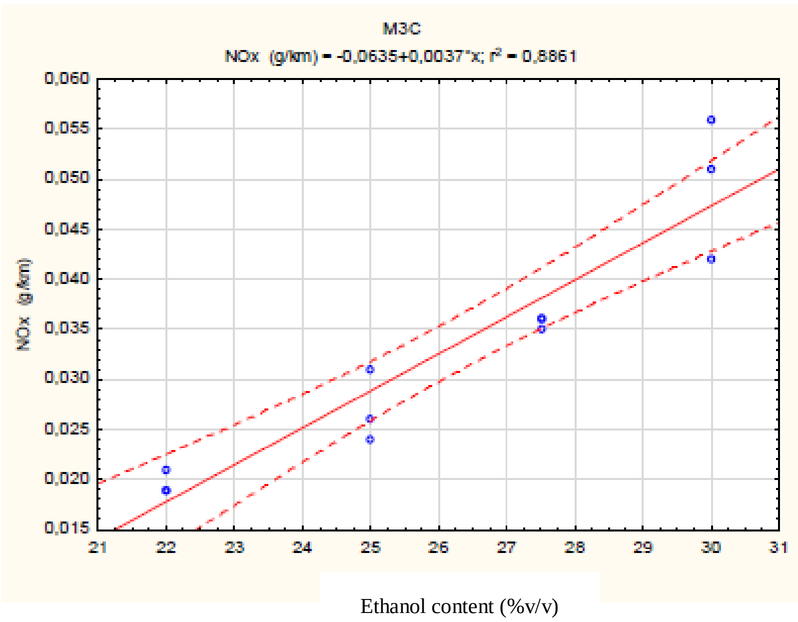


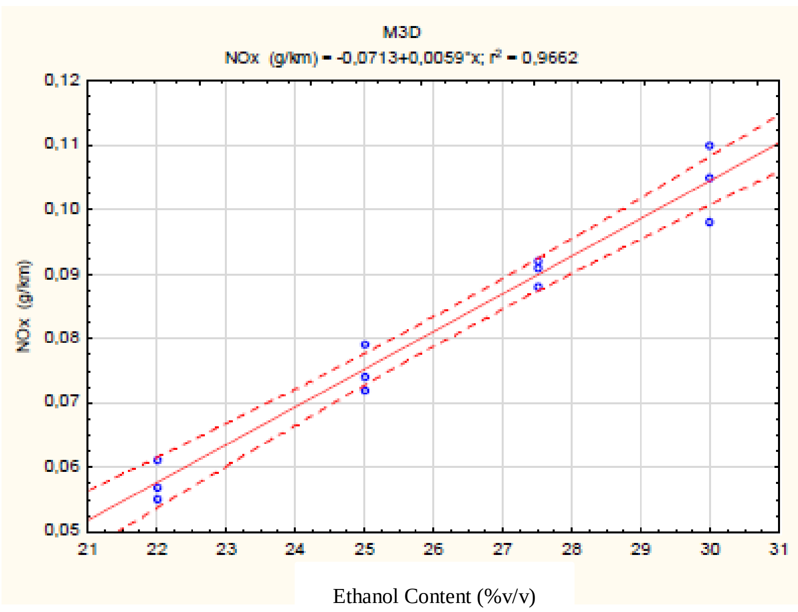
Ethanol Content (%v/v)

CO

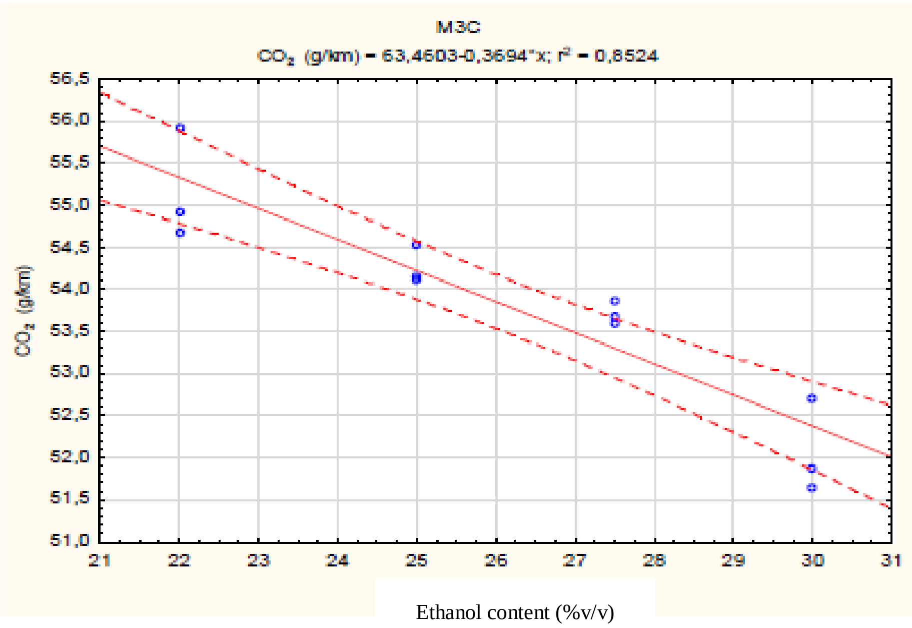

M3C
CO (g/km) = 7,8915-0,2282*x; r² = 0,9717
CO (g/km)
Ethanol Content (%v/v)
M3D
CO (g/km) = 9,2974-0,2917*x; r² = 0,9329
CO (g/km)
Ethanol Content (%v/v)

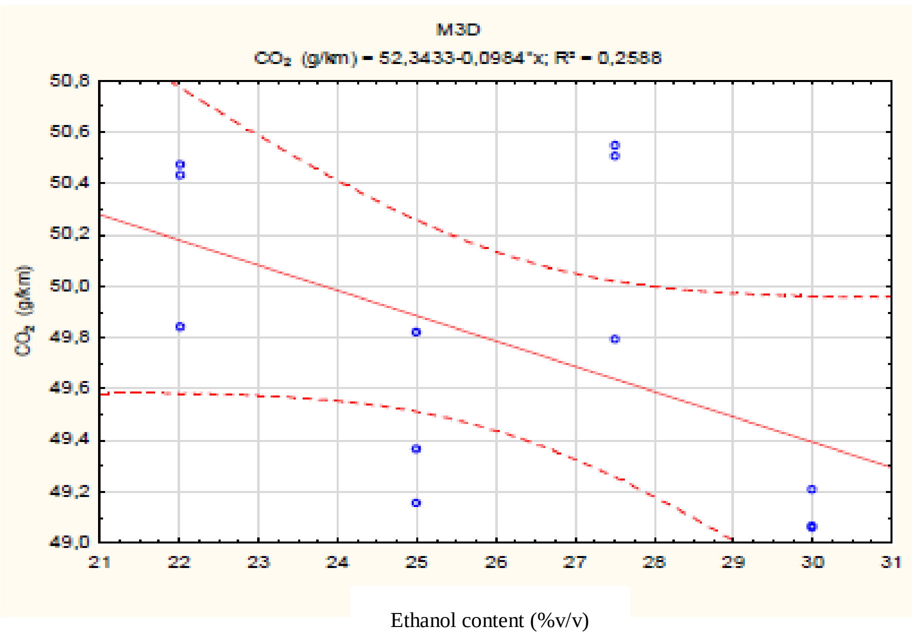
NOx


M3C
NOx (g/km) = -0,0635+0,0037*x; r² = 0,8861
0,060
0,055
0,050
0,045
0,040
0,035
0,030
0,025
0,020
0,015
NOx (g/km)
21
22
23
24
25
26
27
28
29
30
31
Ethanol content (%v/v)

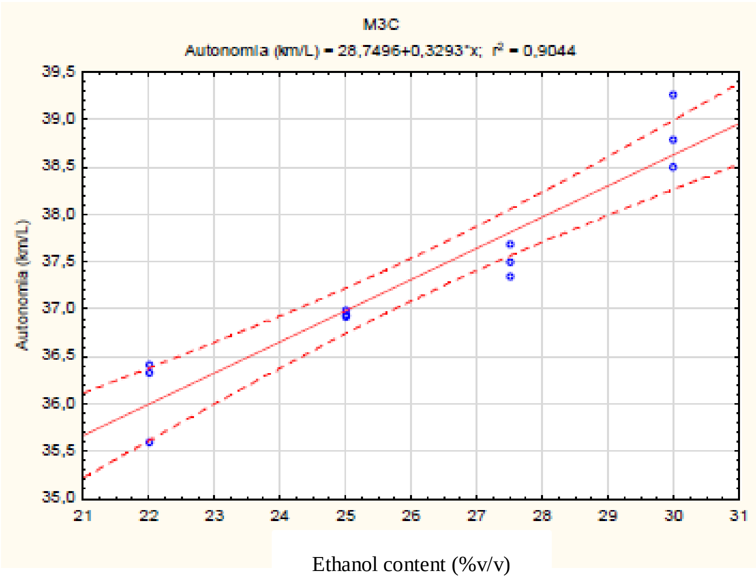

M3D
NOx (g/km) = -0,0713+0,0059*x; r² = 0,9662
0,12
0,11
0,10
0,09
0,08
0,07
0,06
0,05
NOx (g/km)
21
22
23
24
25
26
27
28
29
30
31
Ethanol Content (%v/v)

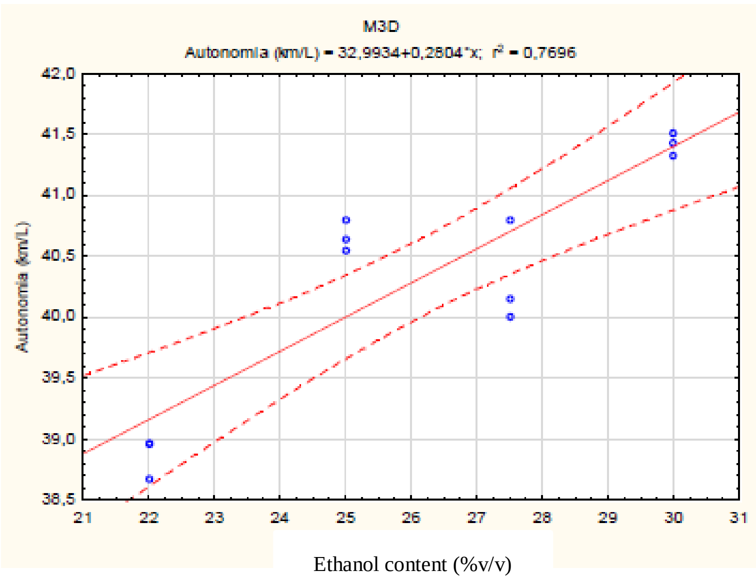
CO_2


M3C
CO₂ (g/km) = 63,4603-0,3694*x; r² = 0,8524
CO₂ (g/km)
56,5
56,0
55,5
55,0
54,5
54,0
53,5
53,0
52,5
52,0
51,5
51,0
21
22
23
24
25
26
27
28
29
30
31
Ethanol content (%v/v)


M3D
CO₂ (g/km) = 52,3433-0,0984*x; R² = 0,2588
CO₂ (g/km)
50,8
50,6
50,4
50,2
50,0
49,8
49,6
49,4
49,2
49,0
21
22
23
24
25
26
27
28
29
30
31
Ethanol content (%v/v)

Fuel Economy





Regression Values for Vehicles

Pollutants	Variables	M3C	M3D
THC	Linear Coeff.	0.194	0.4686
	Angular Coeff.	-0.0016	-0.0096
	E22	0.1588	0.2574
	Conf. Interval E22	0.0119861	0.013921
	E25	0.154	0.2286
	Conf. Interval E25	0.0074837	0.008692
	E27.5	0.15	0.2046
	Conf. Interval E27.5	0.0077126	0.008958
	E30	0.146	0.1806
	Conf. Interval E30	0.0115123	0.013371
CO	Linear Coeff.	7,8915	9,2974
	Angular Coeff.	-0,2282	-0,2917
	E22	2,8711	2,88
	Conf. Interval E22	0,164924	0,331138
	E25	2,1865	2,0049
	Conf. Interval E25	0,1029726	0,206751
	E27,5	1,616	1,27565
	Conf. Interval E27,5	0,1061224	0,213075
	E30	1,0455	0,5464
	Conf. Interval E30	0,1584059	0,318051
NOx	Linear Coeff.	-0,0635	-0,0713
	Angular Coeff.	0,0037	0,0059
	E22	0.0179	0.0585
	Conf. Interval E22	0.005604	0.004639
	E25	0.029	0.0762
	Conf. Interval E25	0.0034989	0.002897
	E27.5	0.03825	0.09095
	Conf. Interval E27.5	0.0036059	0.002985
	E30	0.0475	0.1057
	Conf. Interval E30	0.0053825	0.004456
CO_2	Linear Coeff.	63.46	52.343
	Angular Coeff.	-0.3694	-0.0984
	E22	55.3332	50.1782
	Conf. Interval E22	0.6506091	0.704296
	E25	54.225	49.883
	Conf. Interval E25	0.4062169	0.439737
	E27.5	53.3015	49.637
	Conf. Interval E27.5	0.4186423	0.453188
	E30	52.378	49.391
	Conf. Interval E30	0.6248957	0.676461
	E27.5 x E22	4%	s/dif.
Fuel Economy	Linear Coeff.	28.75	32.993
	Angular Coeff.	0.3293	0.2804
	E22	35.9946	39.1618
	Conf. Interval E22	0.4530476	0.649188
	E25	36.9825	40.003
	Conf. Interval E25	0.2828666	0.405329
	E27.5	37.80575	40.704
	Conf. Interval E27.5	0.291519	0.417728
	E30	38.629	41.405
	Conf. Interval E30	0.4351423	0.623531

ANNEX III

REPORT ON EMISSION AND FUEL ECONOMY TESTS WITH YAMAHA MOTORCYCLES

Content of reference anhydrous ethanol in the reference fuel.

1. Purpose:

To evaluate the impact of the increase in the percentage of reference anhydrous ethanol contained in commercial gasoline on the volume of gases emitted by motorcycles.

2. Standards and procedures for carrying out the tests:

2.1. Cycle EURO 3: European Directive number 97/24

2.2. PROMOT III: CONAMA Resolution number 342/2003

2.3. Fuel adopted according to:

Ethanol, Anhydrous, Reference (EAR): Resolution ANP number 23/2010
Reference gasoline: Resolution ANP number 21/2009-L6

2.4. Number of tests and period during which the tests were carried out:

• Three tests with each fuel for each motorcycle (Yamaha Factor YBR12S and Yamaha T115 Crypton);

• Date of the tests: 08/27/2014 to 09/11/2014

3. Motorcycle used:

Make/Model/Version	Yamaha Factor YBR125	Yamaha T115 Crypton
Chassis	9C6KE1500B0000001	9C6KE1400A0000001
CC	123.7 cm3	113.7 cm3
Fuel	Gasoline	Gasoline
Year/Model	2011	2010
Fuel feeding system	Carbureted	Carbureted
Final odometer reading (km)	1313	1278
Emission level	PROMOT III	PROMOT III

4. Resources

4.1 Emissions lab

Yamaha Motor da Amazônia
Address: Rua Rio Jaraguão, 1842, Bairro Vila Buriti
City: Manaus
State: AM
CEP (Zip Code): 69072-055

4.2 Fuel used for the emission test

Gasool A22	78% of the reference gasoline volume with 22% of ethanol volume
Gasool A25	75% of the reference gasoline volume with 25% of ethanol volume
Gasool A27.5	72.5% of the reference gasoline volume with 27.5% of ethanol volume
Gasool A30	70% of the reference gasoline volume with 30% of ethanol volume

5. Result

5.1 Yamaha Factor YBR125:

Fuel	Date	CO [g/km]	HC [g/km]	NOx [g/km]	CO2 [g/km]	Consumption [km/l]
A22	08/28/2014	1.570	0.196	0.129	55.529	37.097
	08/29/2014	1.514	0.194	0.125	55.205	37.363
	08/29/2014	1.719	0.207	0.145	56.082	36.583
A25	09/02/2014	1.661	0.195	0.126	54.807	37.026
	09/04/2014	1.650	0.204	0.129	54.609	37.145

	08/14/2014	1.792	0.203	0.111	54.446	37.109
A27.5	09/09/2014	1.067	0.169	0.156	53.940	37.886
	09/10/2014	1.031	0.179	0.167	53.775	38.014
	09/11/2014	0.949	0.157	0.177	54.130	37.908
A30	08/22/2014	0.769	0.154	0.195	53.590	38.091
	08/23/2014	0.708	0.228	0.212	54.786	37.193
	08/27/2014	0.433	0.141	0.205	54.042	38.172

5.2. Yamaha T115 Crypton

Fuel	Date	CO [g/km]	HC [g/km]	NOx [g/km]	CO2 [g/km]	Consumption [km/l]
A22	08/27/2014	0.414	0.093	0.107	59.645	35.889
	08/28/2014	0.438	0.095	0.106	60.012	35.647
	08/29/2014	0.410	0.095	0.105	60.042	35.655
A25	09/02/2014	0.426	0.091	0.107	59.697	35.427
	09/03/2014	0.470	0.087	0.107	59.925	35.261
	09/04/2014	0.370	0.098	0.112	58.474	36.196
A27.5	09/09/2014	0.387	0.087	0.133	58.498	35.825
	09/11/2014	0.297	0.092	0.130	58.536	35.878
	09/11/2014	0.382	0.093	0.120	58.392	35.883
A30	08/22/2014	0.232	0.101	0.161	59.247	35.139
	08/23/2014	0.248	0.100	0.165	59.287	35.103
	08/26/2014	0.177	0.085	0.147	57.692	36.160

6. Tables and charts:
6.1. Motorcycle Yamaha Factor YBR125

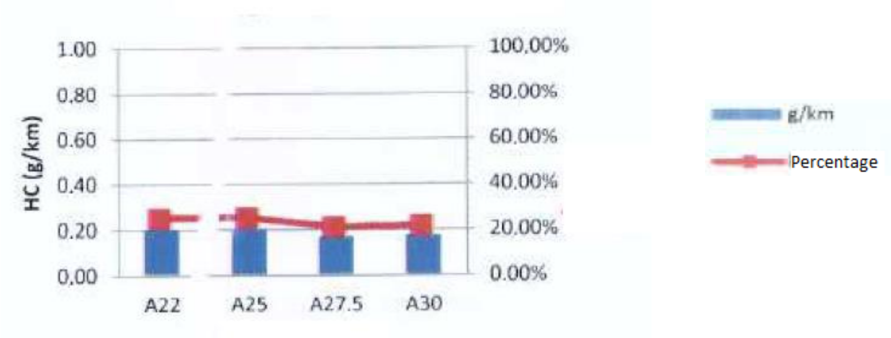
Fuel	Average CO (g/km)	Variation when compared to A22	% of average in relation to Promo 3 limit:
A22	1.601	-	80.05%
A25	1.701	6.25%	85.05%
A27.5	1.016	-36.54%	50.78%
A30	0.637	-60.21%	31.83%
PROMOT CO limit (g/km): 2.0 g/km			

CO (g/km) x Fuel

Fuel

Fuel	Average HC (g/km)	Variation when compared to A22	% of average in relation to Promo 3 limit:
A22	0.199	-	24.88%
A25	0.201	1.01%	25.08%
A27.5	0.168	-15.58%	21.04%
A30	0.174	-12.56%	21.73%
PROMOT HC limit (g/km): 2.0 g/km			

HC (g/km) x Fuel



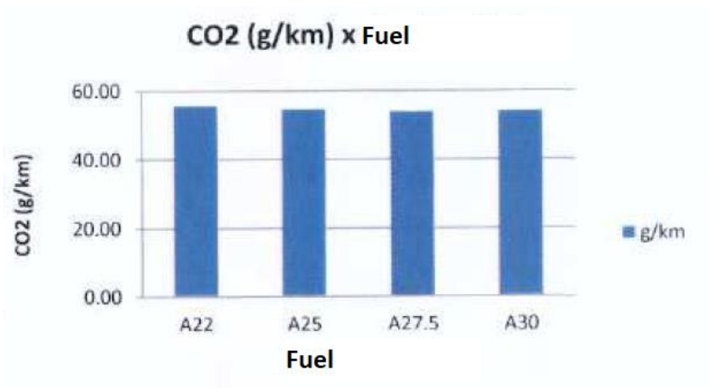
Fuel

Fuel	Average NOx (g/km)	Variation when compared to A22	% of average in relation to Promo 3 limit:
A22	0.133	-	88.67%
A25	0.122	-8.27%	88.33%
A27.5	0.167	25.56%	111.11%
A30	0.204	53.38%	136.00%
PROMOT NOx limit (g/km): 0.15 g/km			

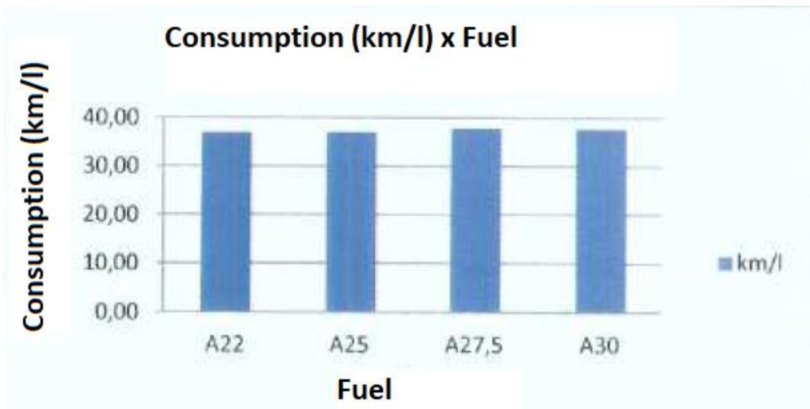
NOx (g/km) x Fuel

Fuel

Fuel	Average CO2 (g/km)	Variation when compared to A22
A22	55.605	-
A25	54.621	-1.77%
A27.5	53.948	-2.98%
A30	54.139	-2.64%



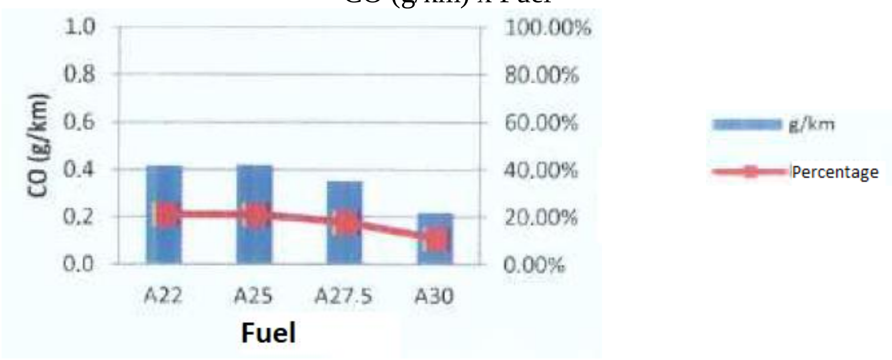
Fuel	Average Consumption (g/km)	Variation when compared to A22
A22	37.014	-
A25	37.093	0.21%
A27.5	37.936	2.49%
A30	37.819	2.17%



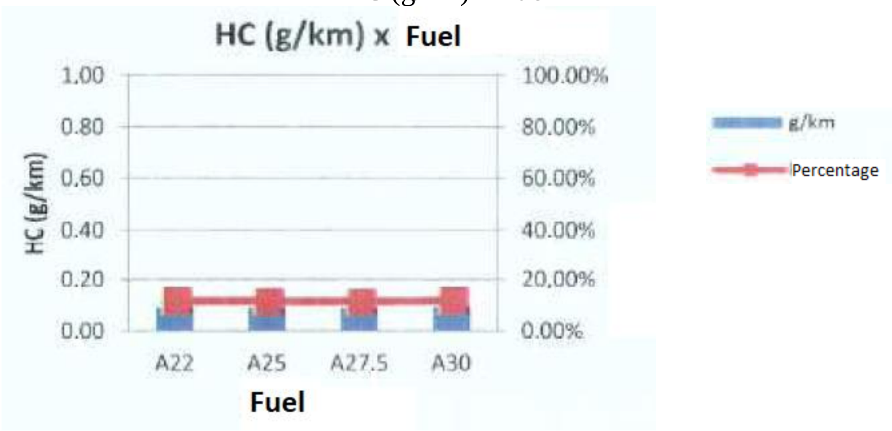
6.2. Motorcycle Yamaha T115 Crypton

Fuel	Average CO (g/km)	Variation when compared to A22	% of average in relation to Promo 3 limit:
A22	0.421	-	21.03%
A25	0.422	0.24%	-21.10%
A27.5	0.355	-15.68%	17.77%
A30	0.219	-47.98%	10.95%
PROMOT CO limit (g/km): 2.0 g/km			

CO (g/km) x Fuel

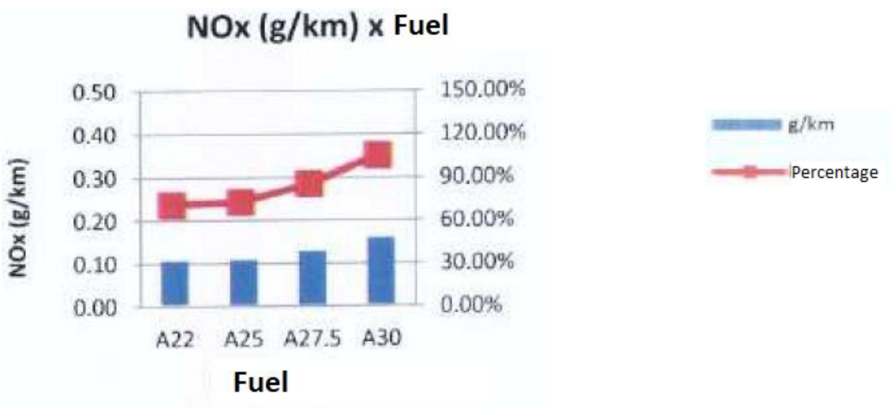


HC (g/km) x Fuel

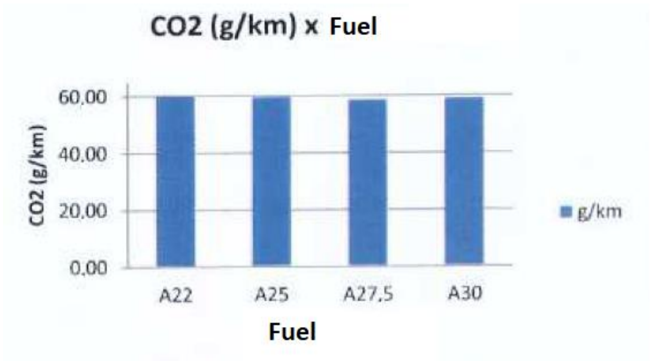


Fuel	Average HC (g/km)	Variation when compared to A22	% of average in relation to Promo 3 limit:
A22	0.094	-	11.79%
A25	0.095	-2.13%	11.50%
A27.5	0.091	-3.19%	11.33%
A30	0.095	1.06%	11.92%
PROMOT HC limit (g/km): 0.8 g/km			

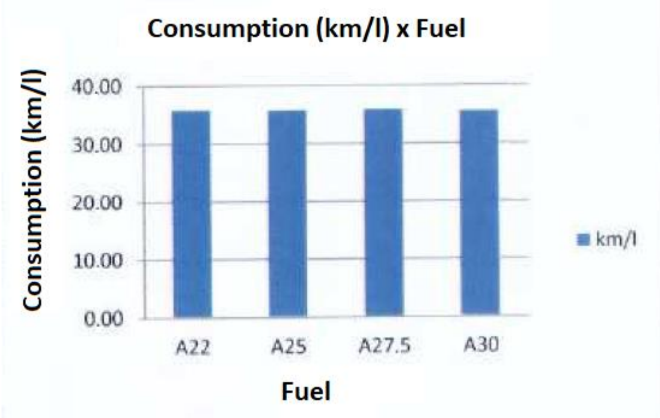
Fuel	Average NOx (g/km)	Variation when compared to A22	% of average in relation to Promo 3 limit:
A22	0.106	-	70.67%
A25	0.109	2.83%	72.44%
A27.5	0.128	20.75%	85.11%
A30	0.158	49.06%	105.11%
PROMOT NOx limit (g/km): 0.15 g/km			



Fuel	Average CO2 (g/km)	Variation when compared to A22
A22	59.900	-
A25	59.365	-0.89%
A27.5	58.475	-2.38%
A30	58.742	-1.93%



Fuel	Average Consumption (g/km)	Variation when compared to A22
A22	35.730	-
A25	35.628	-0.29%
A27.5	35.862	0.37%
A30	35.467	-0.74%



7. Analysis of the results:
The following are the results of the emission tests carried out with Yamaha T115 Crypton and Yamaha Factor YBR125:

- Variation in CO (g/km):
  - For fuels A22 with A25: there was a variation of (0.24%; 6.25%)
  - For fuels A22 with A27.5: there was a greater percentage variation (15.68%; - 36.54%),
  - For A22 fuels with A30: there was a greater variation (47.98%; -60.21%)
- HC variation (g / km):
  - For fuels A22 with A25: there was a variation of (-2.13%; 1.01%)
  - For fuels A22 with A27.5: there was a greater percentage variation (-3.19%; - 15.58%),
  - For A22 fuels with A30: there was a greater variation (1.06%; -12.56%)
- NOx (g / km):
  - For A22 fuels with A25: there was a small variation (2.83%; -8.27%)
  - For fuels A22 with A27.5: there was a greater percentage variation (20.75%, 25.56%)
  - For A22 fuels with A30: there was a greater variation (49.06%, 53.38%)

8. Conclusion:

- In the tests carried out with the Yamaha Factor YBR125 and Yamaha T115 Crypton motorcycles, it was observed that:
  - For HC (g/km), C02 (g/km) and Consumption (km/l): There was a small decrease in the percentage variation;
  - For CO (g/km): There was a significant reduction with the increase of the Ethanol, Anhydrous, Reference (EAR);
  - NOx (g/km): There was a significant increase for all fuels analyzed;

In mixtures with ethanol content up to 25%, it was found that there was no significant difference for the parameters analyzed. This is due to the fact that the motorcycles are equipped with a technology developed for this percentage.
For mixtures with a content above 25%, there was a significant decrease in CO and a significant increase in NOx due to the "imbalance" of the stoichiometric ratio (air / fuel) caused by the increase in the percentage of Anhydrous Reference Ethanol (EAR), thereby causing the mixture to be poorer.
As a result, the NOx values (g/km) not only increased, but also exceeded the regulated limits in PROMOT 3. Thus, it is possible to expect that this situation may occur with other motorcycles of different makes and models that have been developed to meet the limits established in PROMOT 3.
Other considerations:
• For motorcycles manufactured to address the previous phase (PROMOT 2), where the limits are more lenient, this impact will be even greater due to the technology adopted in the gas and emission control components.

City of Manaus, September 29, 2014.

LUCIO NOBUYUKI TIBA
Manager