Different Hydrous Ethanol-Gasoline Blends – FTIR Emissions of a Flex-Fuel Engine and Chemical Properties of the Fuels

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Aviso

As apresentações podem conter previsões acerca de eventos futuros. Tais previsões refletem apenas expectativas dos administradores da Companhia. Os termos “antecipa", "acredita", "espera", "prevê", "pretende", "planeja", "projeta", "objetiva", "deverá", bem como outros termos similares, visam a identificar tais previsões, as quais, evidentemente, envolvem riscos ou incertezas previstos ou não pela Companhia. Portanto, os resultados futuros das operações da Companhia podem diferir das atuais expectativas, e o leitor não deve se basear exclusivamente nas informações aqui contidas. A Companhia não se obriga a atualizar as apresentações e previsões à luz de novas informações ou de seus desdobramentos futuros. Os valores informados para 2010 em diante são estimativas ou metas.

Esta apresentação é de caráter meramente informativo, não constituindo uma oferta, convite ou solicitação de oferta de subscrição ou compra de quaisquer valores mobiliários no Brasil ou em qualquer outra jurisdição e, portanto**, não devendo ser utilizado como base para qualquer decisão de investimento.**

Motivation

- ✓ **Hydrous Ethanol is used only on Brazil.**
- ✓ **Flex-Fuel Vehicles (2010): Represented over 85% of new vehicles sold in Brazil.**
- ✓ **Ethanol blends on gasoline: very few papers with engine emissions of aldehydes and unburned ethanol data.**
- ✓ **Reliable experimental data: Important for models calibration. With FID (Flame Ionization Detector) – wrong analysis of HC due to ethanol and aldehydes.**
- ✓ **Use of FTIR for emission measurement of ethanol and aldehydes.**
- ✓ **Continue research of ethanol/gasoline blends on Flex-Fuel engines**

Objective

- ✓ STUDY FLEX-FUEL ENGINE EMISSIONS AND PERFORMANCE OF DIFFERENT HYDROUS ETHANOL/GASOLINE BLENDS .

- ✓ BETTER UNDERSTAND ETHANOL EFFECTS ON ENGINE EMISSIONS UNBURNED ETHANOL, ALDEHYDES AND HYDROCARBONS BY USING FTIR (FOURIER INFRARED ANALYZER).

- ✓ SUPPLY RELIABLE EXPERIMENTAL DATA FOR COMPUTER SIMULATION.

EXPERIMENTAL INSTRUMENTATION

INTAKE AIR CONDITIONER

(Humidity ~ 50%, T=20°C)

FUEL CONSUMPTION MEASURE

T ~ 20℃
Instantaneous and accumulated (kg/h)

EXPERIMENTAL INSTRUMENTATION

AUTOMATION SYSTEM

✓ **AVL PUMA OPEN system:**

. Temperatures, Pressure, etc

. Throttle opening

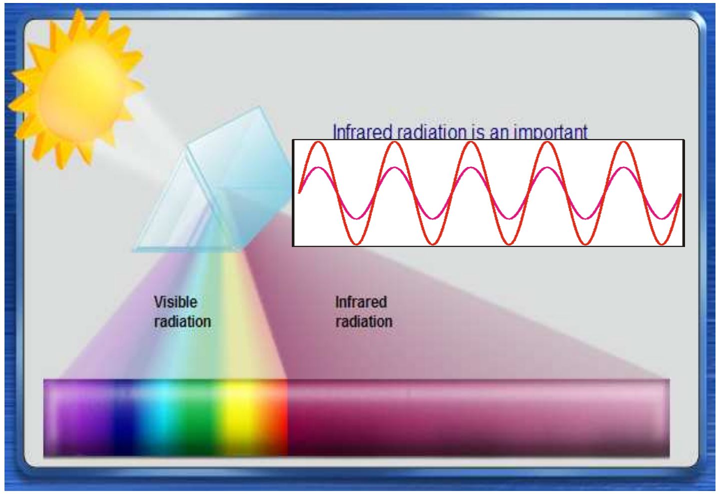
. Fuel Consumption data

. Air Flow

✓ **Eddy current dyno:**

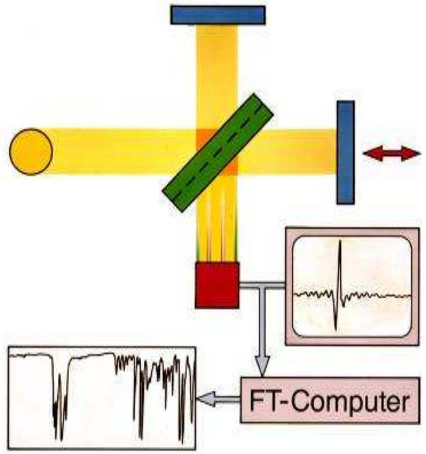
Schenck W130

FTIR - FOURIER TRANSFORM INFRARED ANALYZER

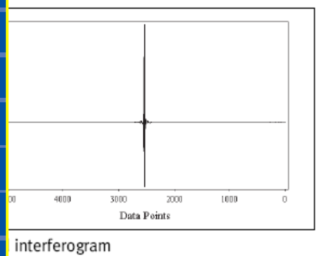


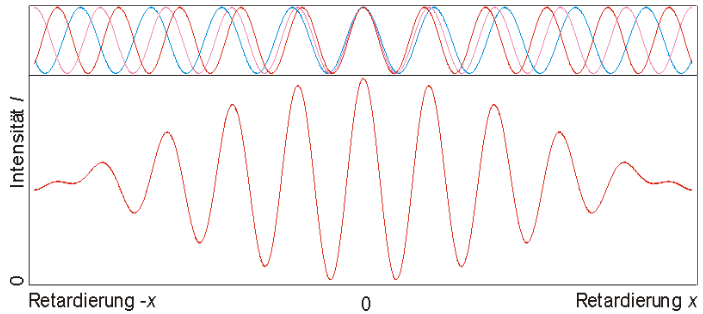
AVL- SESAM FTIR

Diesel / Gasoline
HC-Gasoline
HC-Diesel
C_2H_2 (Acetylene)
C_2H_4 (Ethylene)
C_2H_6 (Ethan)
C_3H_6 (Propylene)
C_4H_6 (1.3 Butadiene)
NC_5 (n- Pentane)
IC_5 (iso- Pentane)
NC_8 (n-Octane)
AHC (Aromatic HC)
SO_2 (Sulfur Dioxide)
COS (Carbonyl sulfide)
N_2O (Nitrous oxide)
NH_3 (Ammonia)
CH_2O (Formaldehyde)



FTIR Interferometer





ENGINE AND CONTROL UNITY

✓ **Fiat FIRE 1.4 L TETRAFUEL**

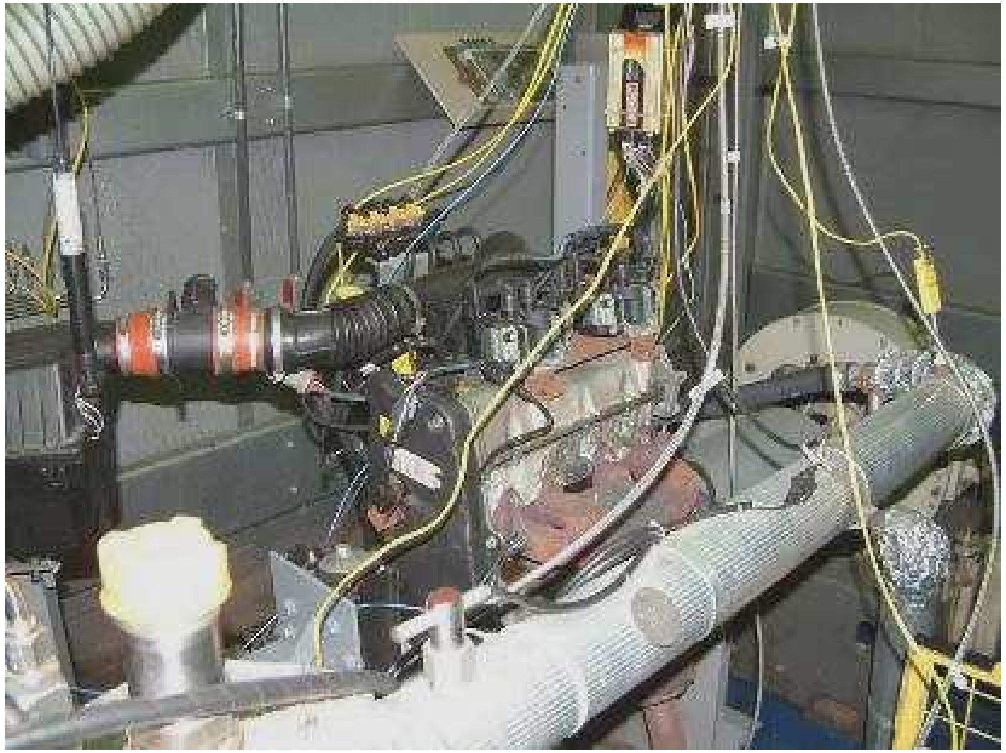
✓ **4 cil. , 16 v , Tax : 10.35:1**

	Gasoline 20%	**Ethanol H100**
Torque (Nm) (2250 rpm)	**120**	**122**

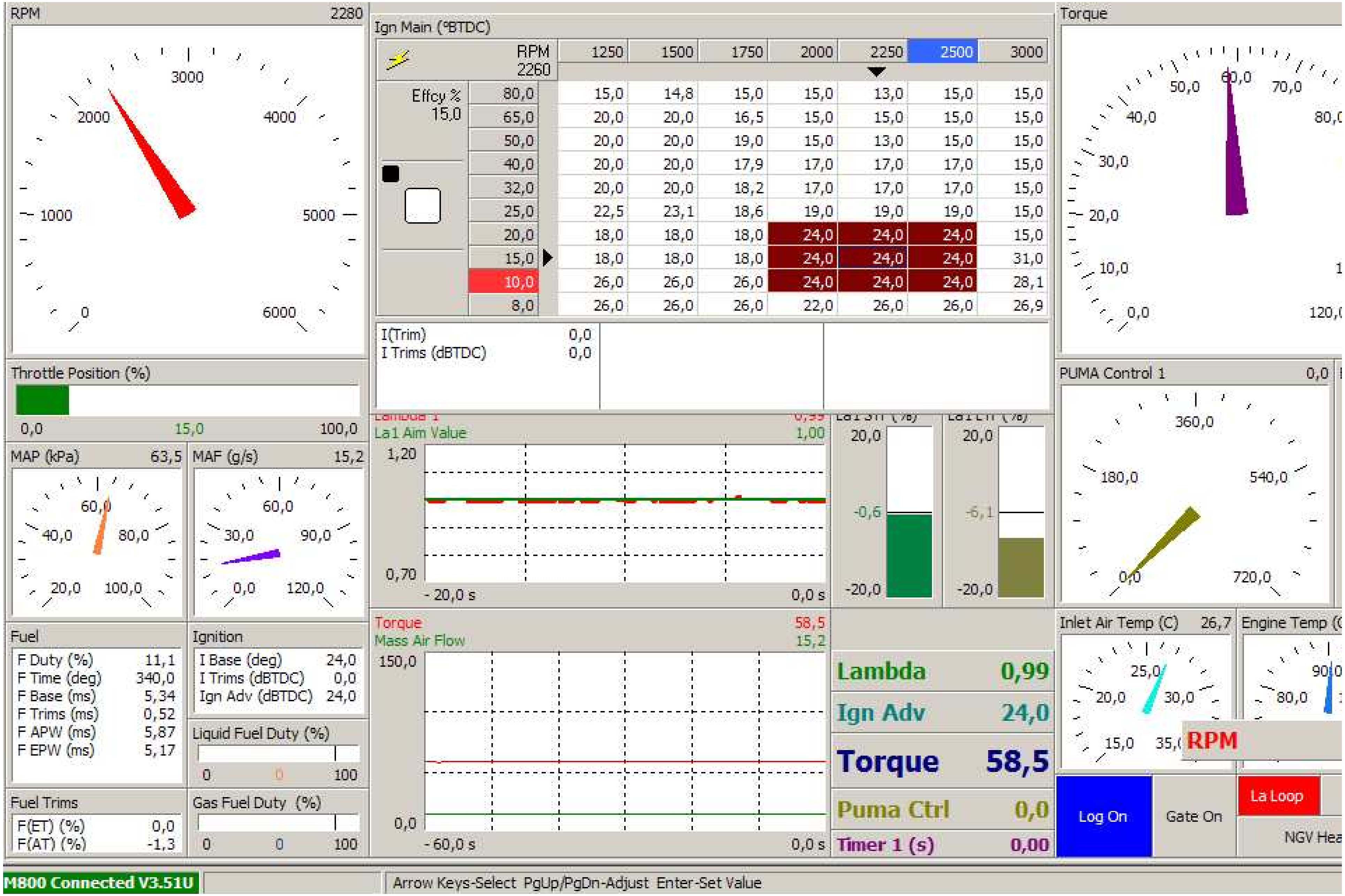
- **Programable ECU MoTeC M800**
- **Control:**

- *AF*, spark timing, injection time, throttle

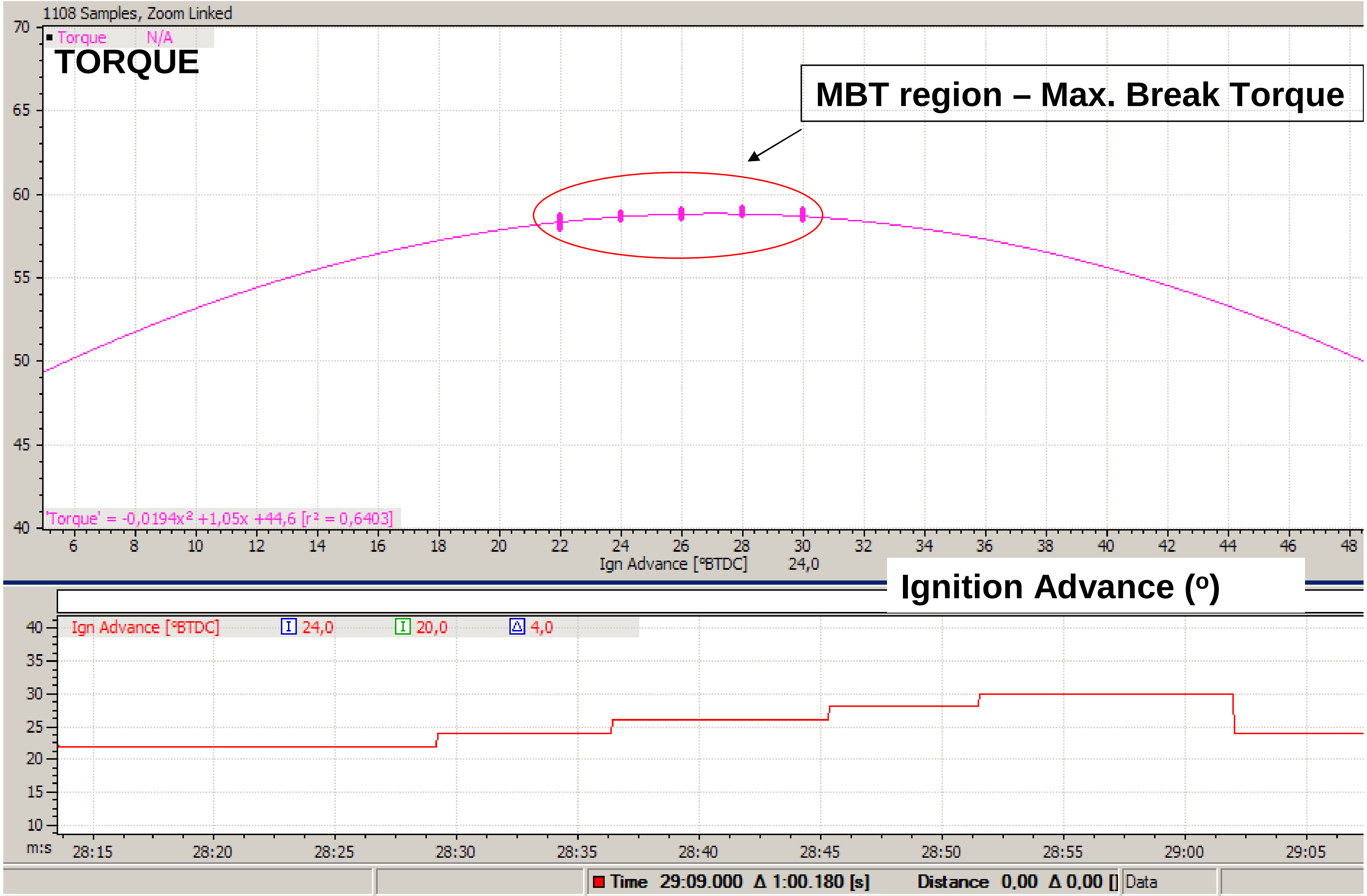
- **Map optimization**
- **LAMBDA - ETAS**



MoTec – Map optimization



MoTec – Torque Maximization



MAIN properties OF GASOLINE X HYDROUS ETHANOL BLENDS

	Gasoline	Hydrous Ethanol			
	E25 (H0)	H30	H50	H80	H100
Density (kg/m³)	748,2	764,9	779,2	797,7	808,7
MON	85,1	88	89,7	91,6	91,8
RON	97,3	>100	>100	>100	>100
Carbon (%)	73,3	64,3	59,5	53,9	50,7
Hydrogen (%)	13,7	13,4	13,3	13,1	13,0
Oxygen (%)	13,0	22,3	27,2	33,0	36,3
Equivalent Fuel	$C\ H_{2,2}\ O_{0,13}$	$C\ H_{2,5}\ O_{0,26}$	$C\ H_{2,7}\ O_{0,34}$	$C\ H_{2,9}\ O_{0,46}$	$C\ H_{3}\ O_{0,53}$
LHV (MJ/kg)	38,92	34,68	31,84	27,59	24,76
RVP (kPa)	55,9	52,5	47,2	33,0	15,4

- EQUIVALENT FUEL: CHyOz

- $$A/F = \frac{138{,}8*(y/4 + 1 - z/2)}{12 + y + 16z}$$

A/F VALUES – CALCULATED BASED ON CHyOz ANALYSIS:

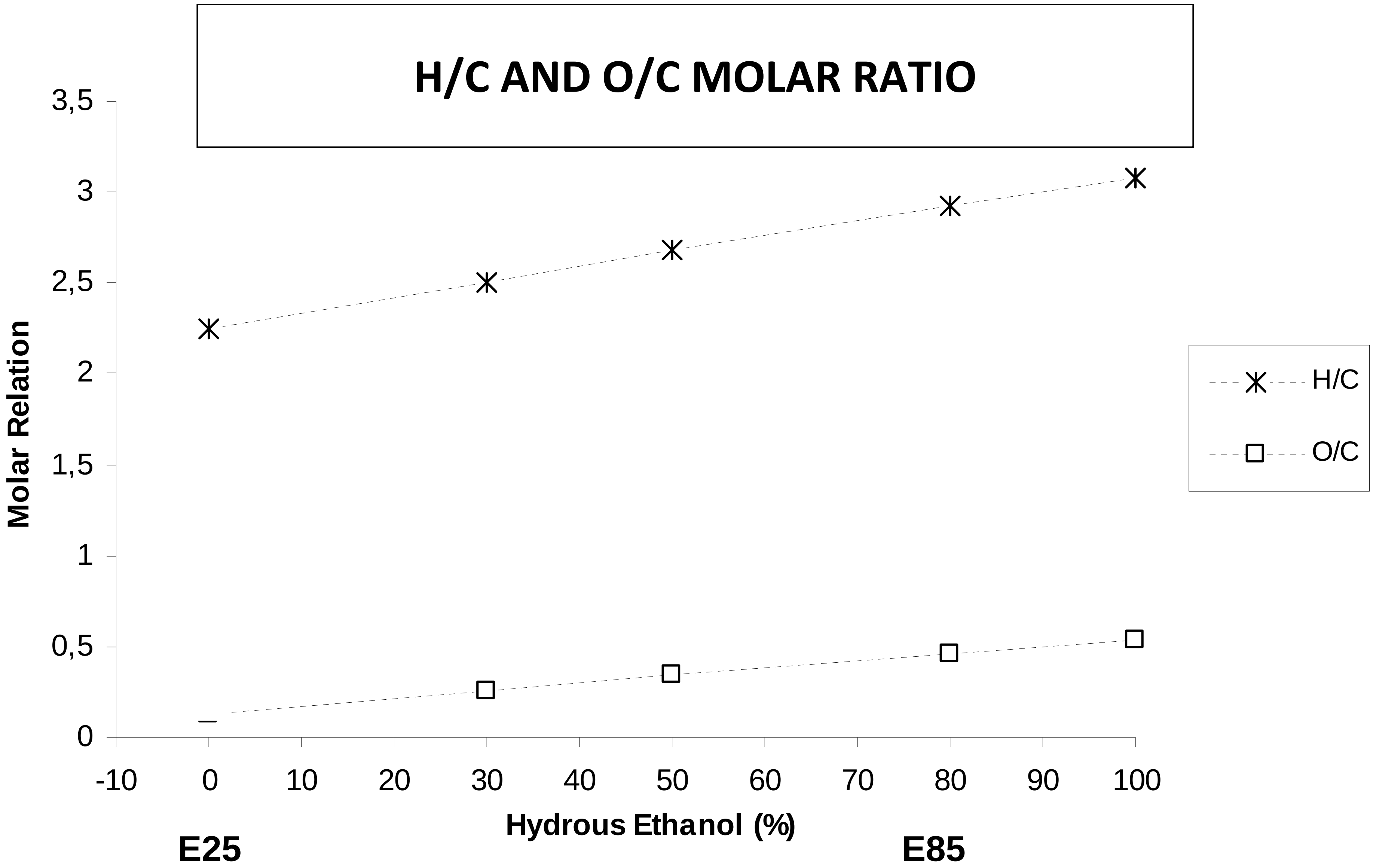
-**E25 – 12,7**

-**H30 – 11,1**

-**H50 – 10,3**

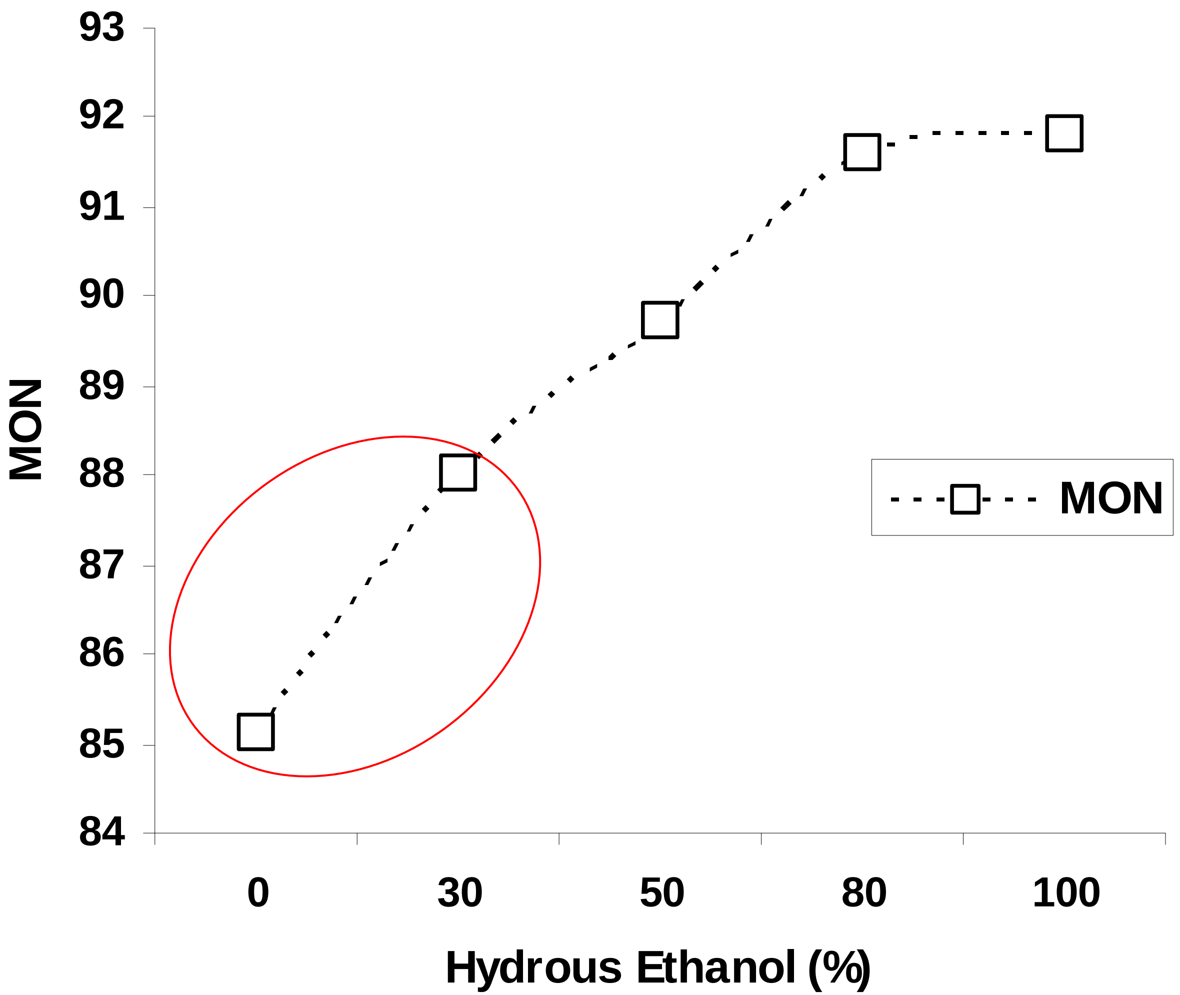
-**H80 – 9,35**

-**H100 – 8,8**



H/C AND O/C MOLAR RATIO
3,5
3
2,5
2
1,5
1
0,5
0
Molar Relation
-10
0
10
20
30
40
50
60
70
80
90
100
Hydrous Ethanol (%)
E25
E85
H/C
O/C

MON X HYDROUS ETHANOL

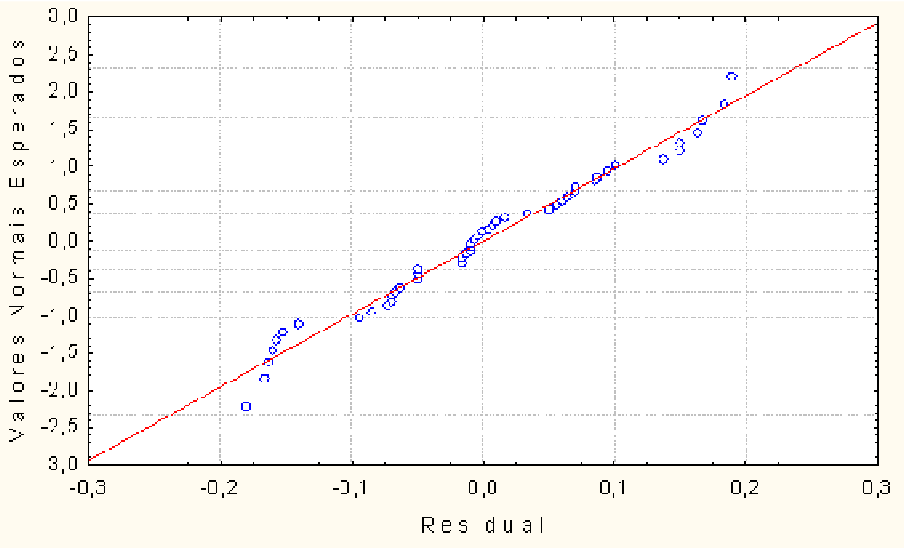


EXPERIMENTAL PROCEDURE

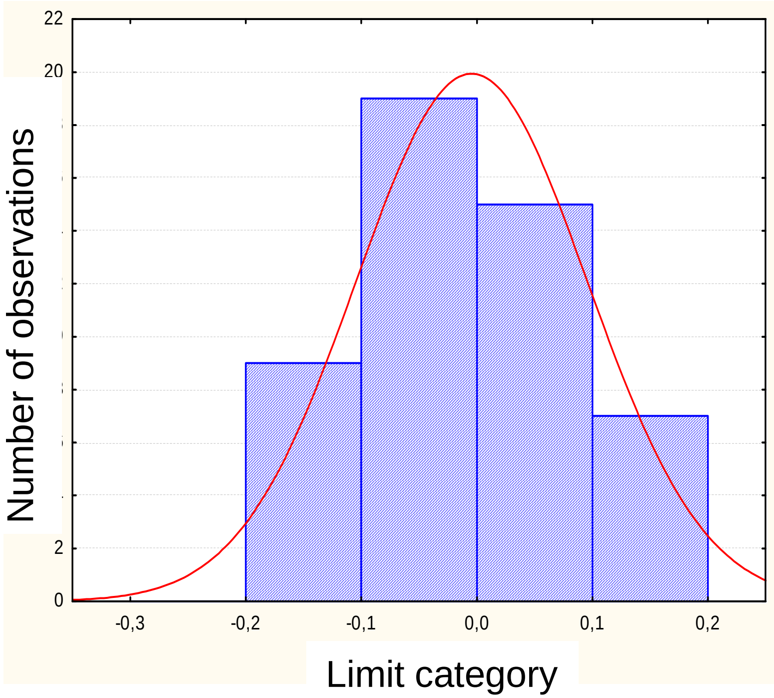
- ✓ TORQUE: 60 Nm
- ✓ RPM: 1500, 2500 E 3875
- ✓ Lambda= 1
- ✓ SPARK TIMING - MBT
- ✓ FUELS: E25 (H0), H30, H50, H80 and H100
- ✓ EACH OPERATING POINT WAS TESTED AT LEAST 3 TIMES TO ALLOW STATICAL DATA HANDLING.
- ✓ EMISSIONS WITH FTIR: CO, HC, NOx, ALDEHYDES AND ETHANOL.

STATISTICS HANDLING – STATISCA SOFTWARE

Normality of residues



Histogram



- **Outliers**
- **Normal distribution if p>0,05, for 95% confidence level**
- **Tests: Shapiro-Wilk (p>0,09207), Lilliefors (p>0,20) and Kolmogorov-Smirnov (p>0,20), FISHER (ANOVA)**

CALCULATION of g/kWh

ref. CFR 2009 – TITLE 40 – vol. 20-part 91 – subpart E

$$W_{NO_X} = (G_{AIRD} + G_{FUEL}) \times \frac{M_{NO_2}}{M_{exh}} \times WNO_X \times K_H \times \frac{1}{10^6}$$

$$W_{HC} = (G_{AIRD} + G_{FUEL}) \times \frac{M_{HCexh}}{M_{exh}} \times WHC \times \frac{1}{10^6}$$

$$W_{CO} = (G_{AIRD} + G_{FUEL}) \times \frac{M_{CO}}{M_{exh}} \times WCO \times \frac{1}{10^2}$$

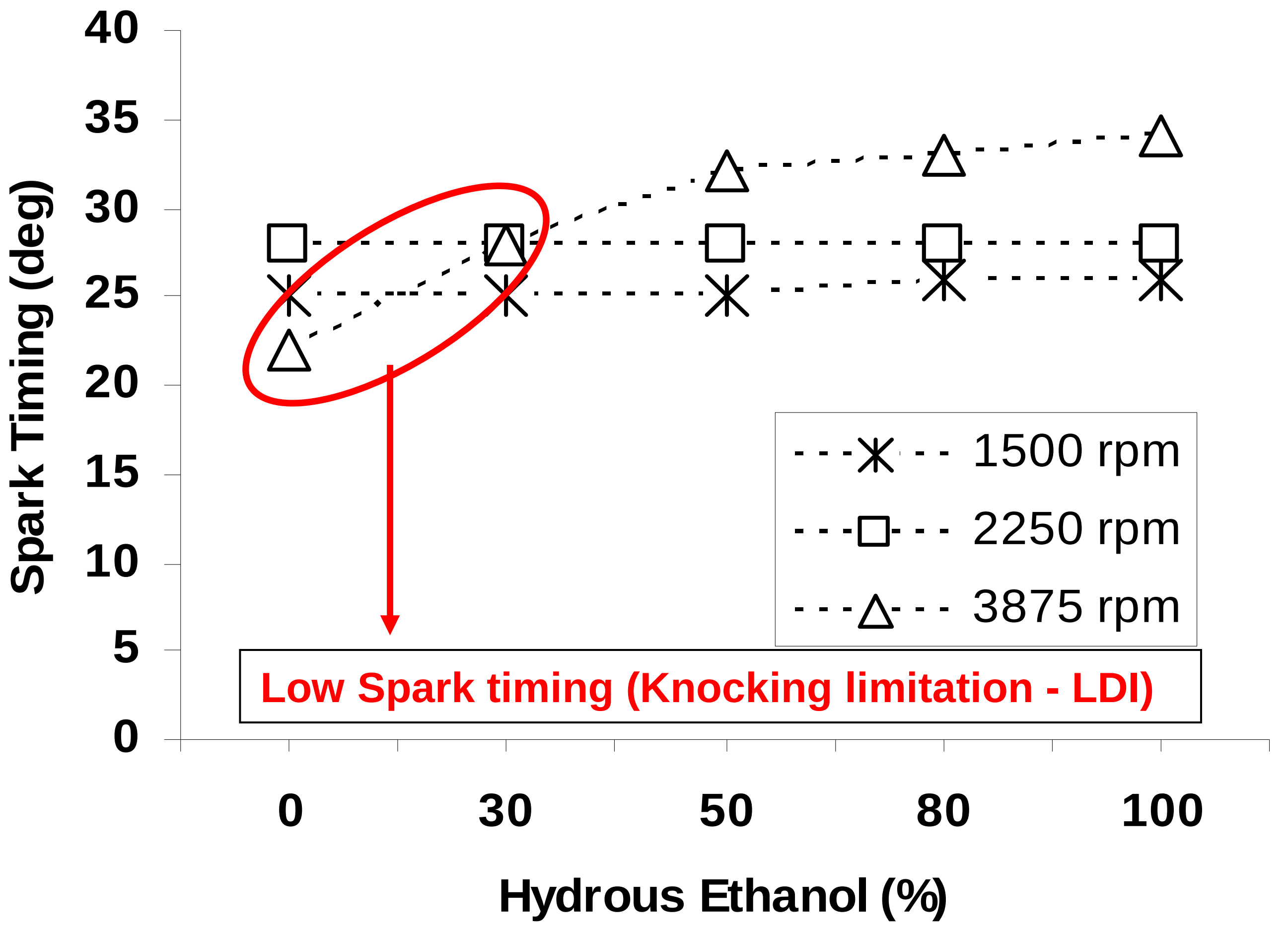
$M_{HCexh} = 12.01 + 1.008 \times \alpha$

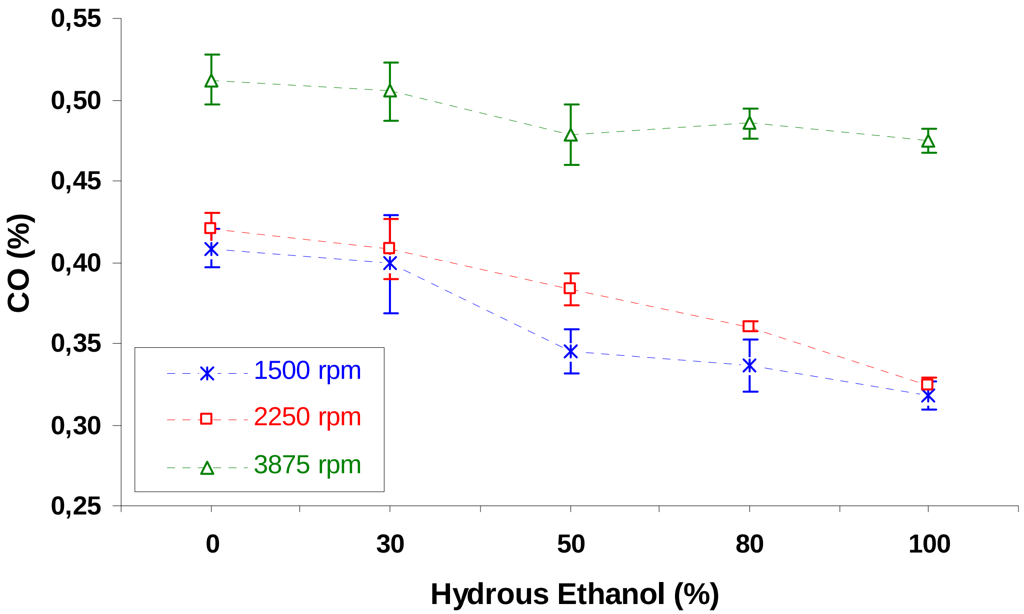
Where:

α=Hydrocarbon/carbon atomic ratio of the fuel.

M_{exh}=Molecular weight of the total exhaust;

SPARK TIMING
Partial load , λ = 1

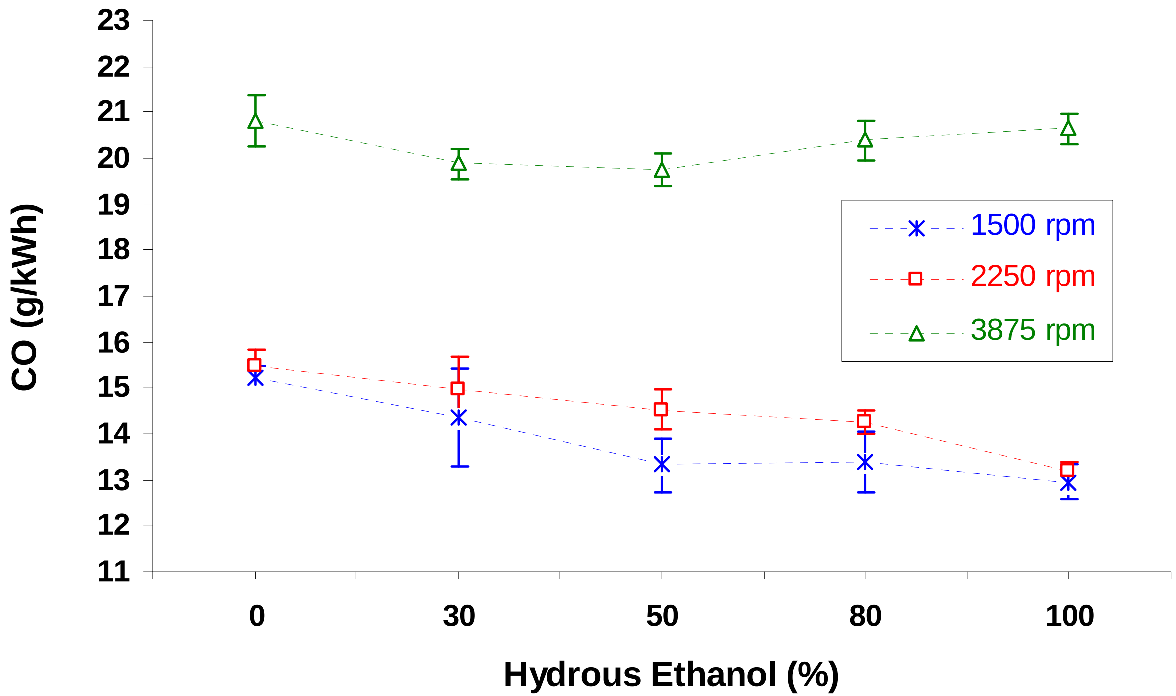


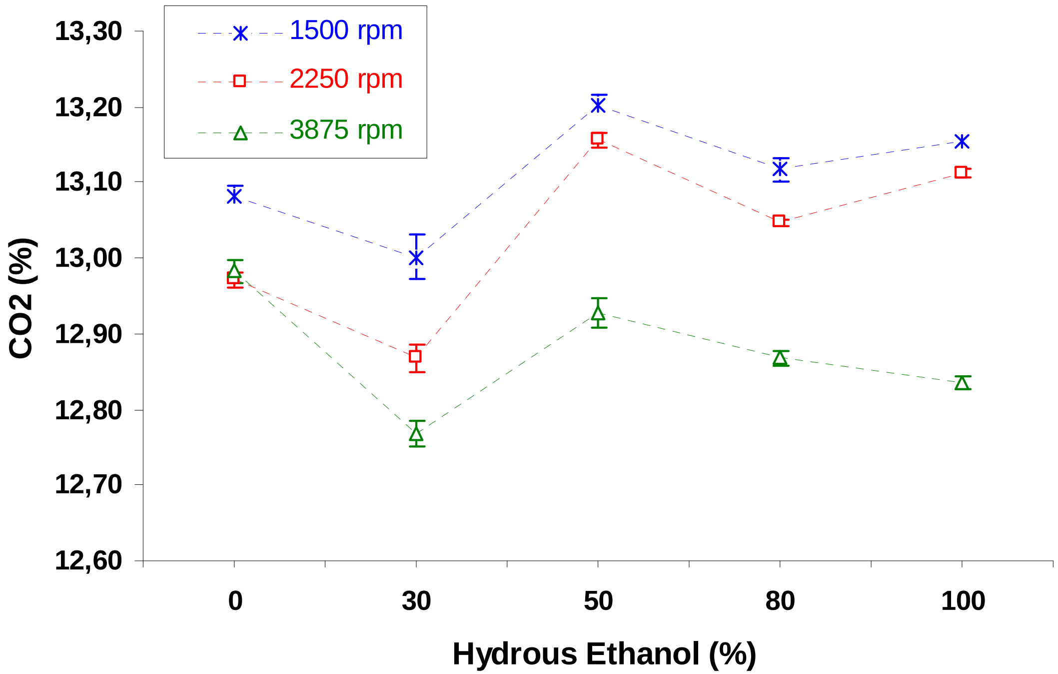


CO with Ethanol increase:

- ↓ 1500 & 2500 rpm

- 3875 rpm – no change

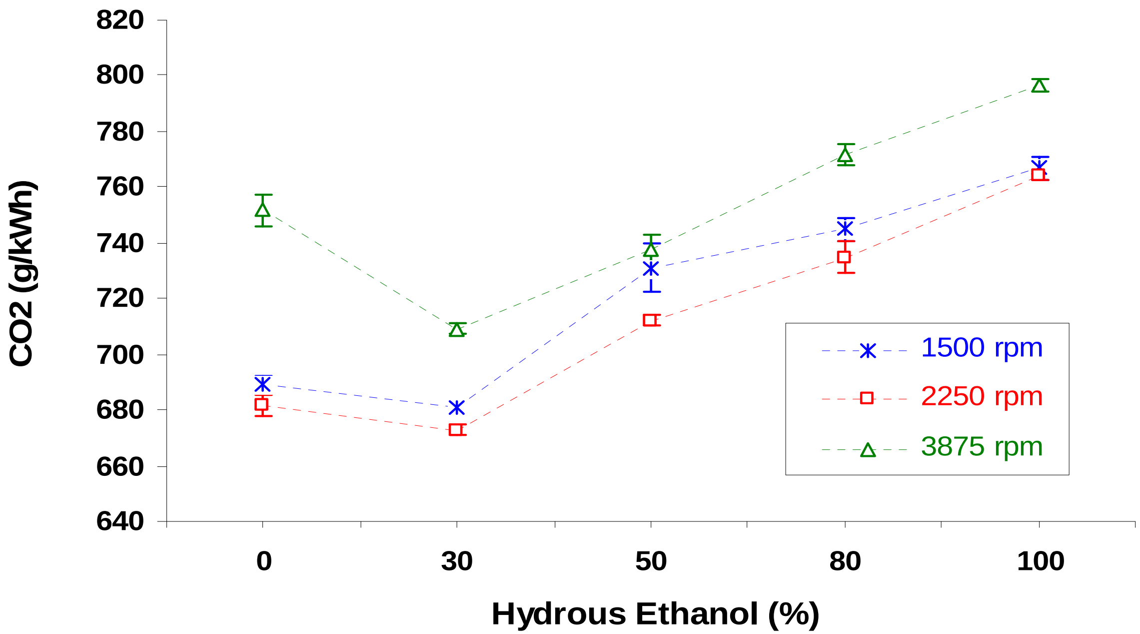


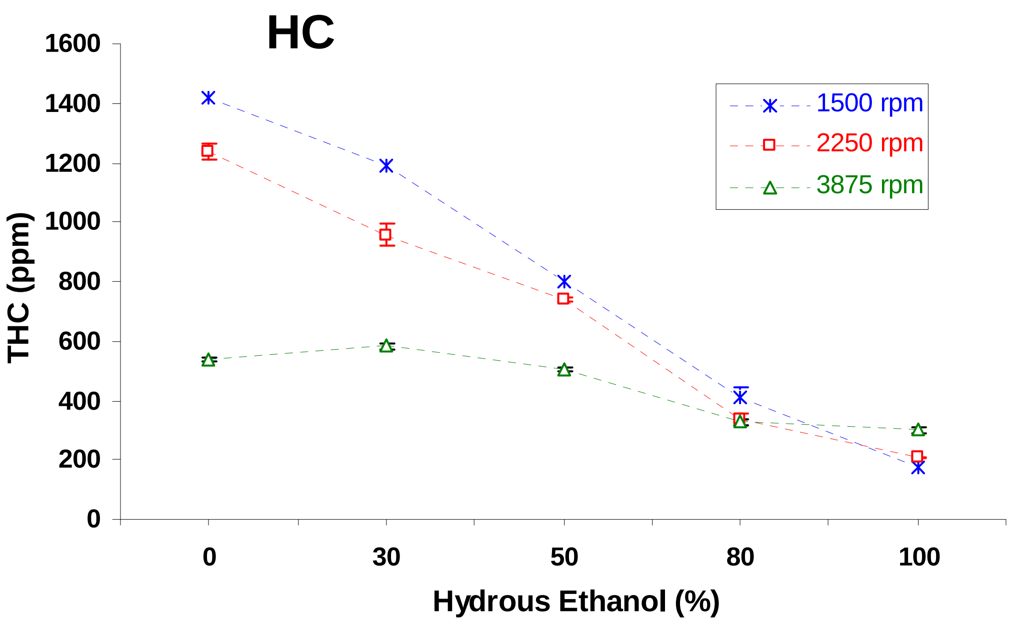


CO2 g/kWh Increases due to:

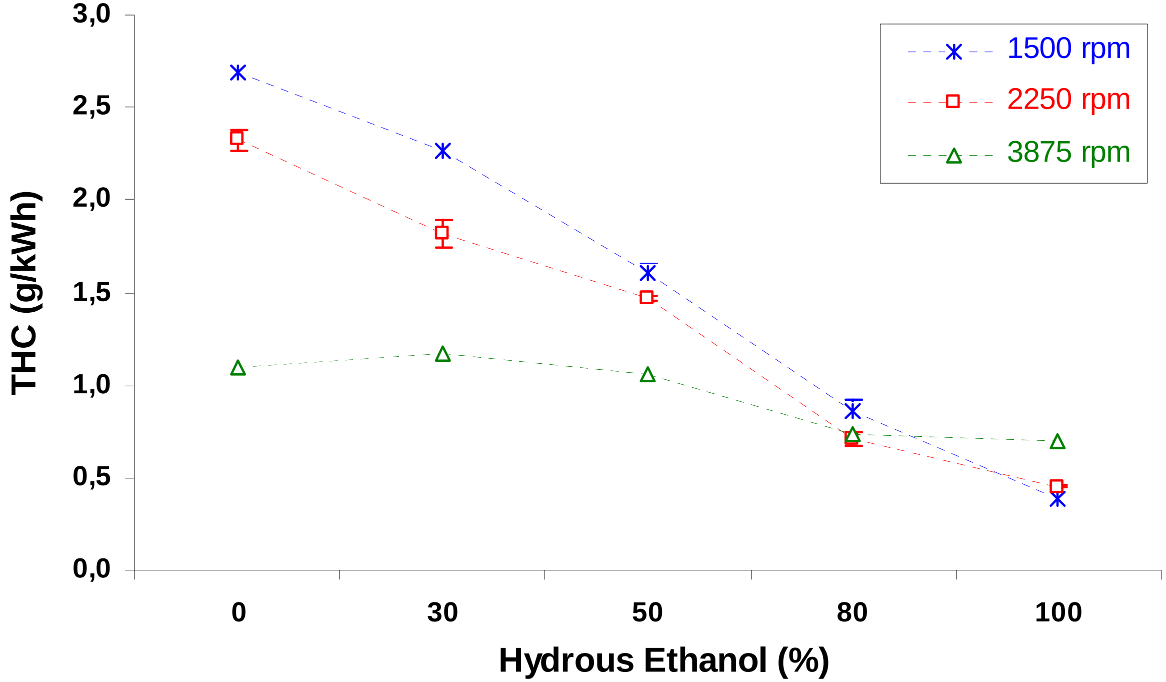
-CO conversion into CO2

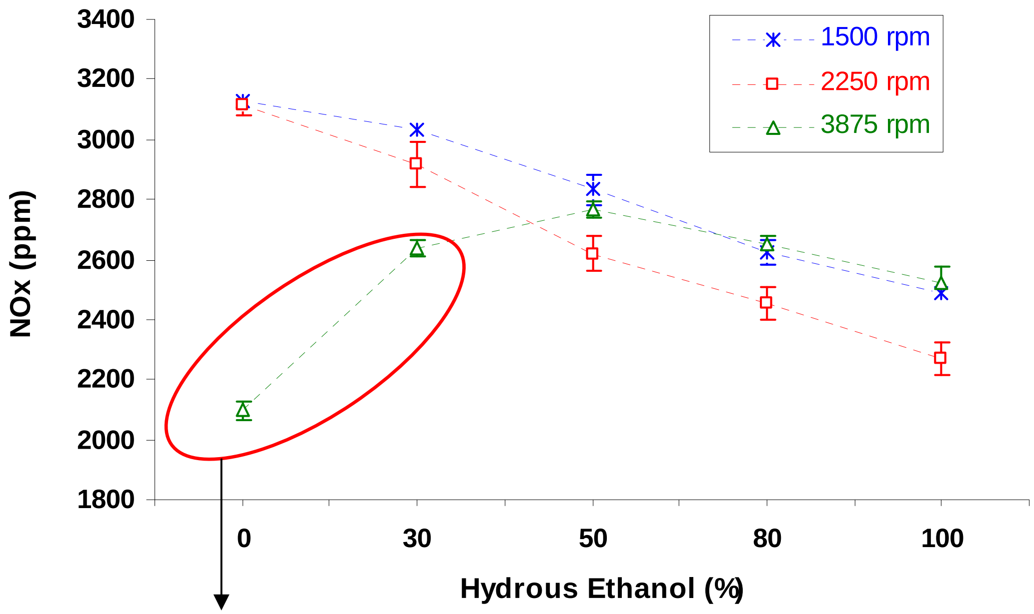
-Increase of Fuel consumption





HC - just Hydrocarbon without ethanol and aldehyde

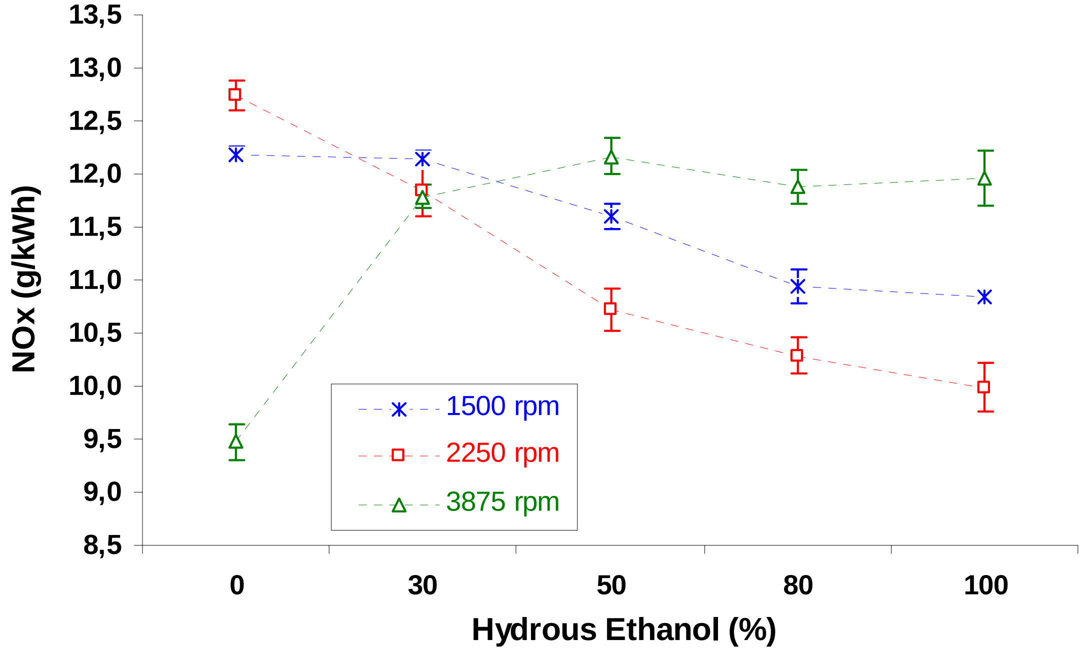


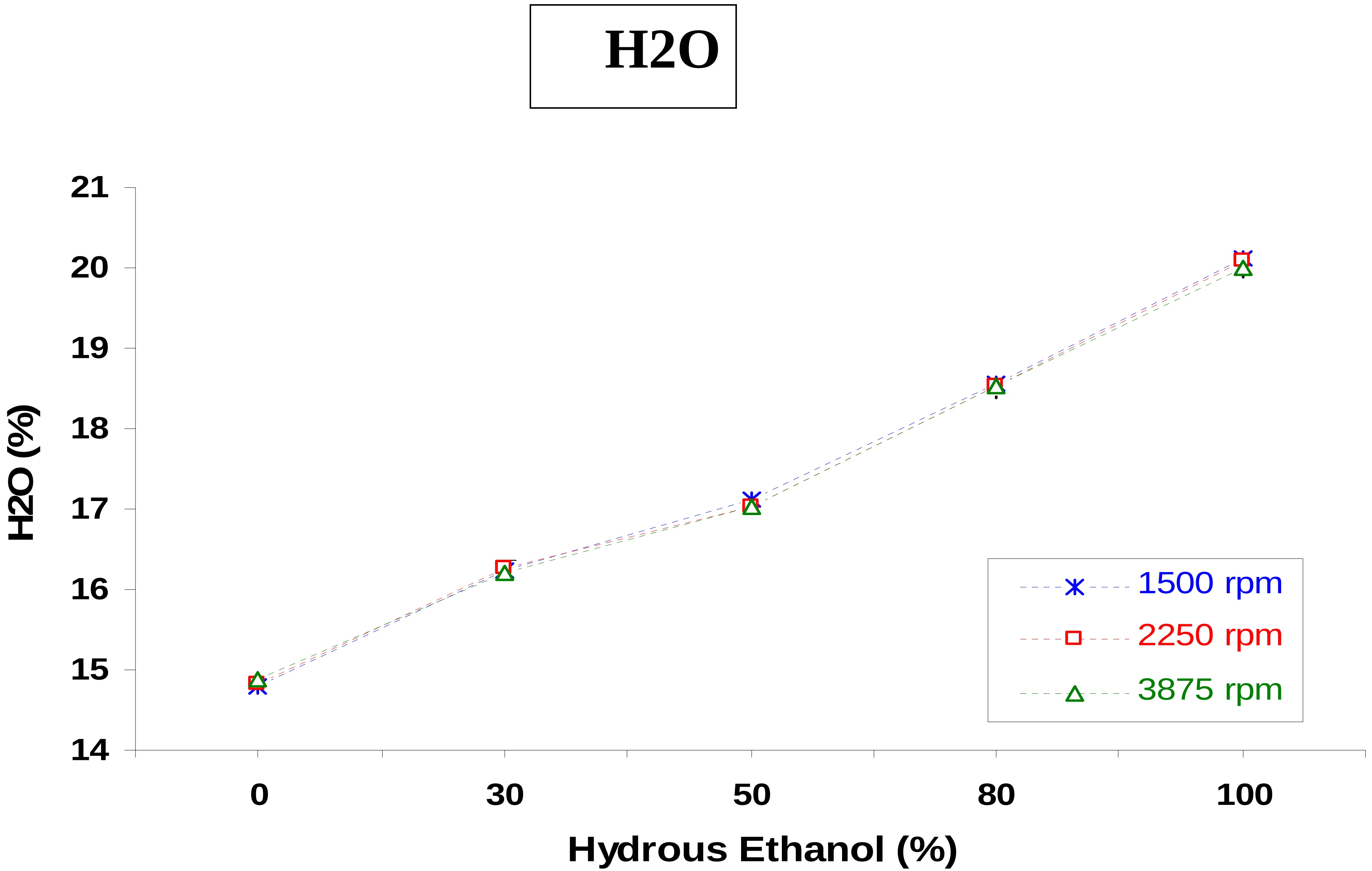


NOx:

- ⬇ **for 1500 & 2250, due to lower N2 available.**
- **3875 rpm – knocking limitation E25 and H30 lower values than expected. (chamber temperature reduction).**

KNOCKING LIMITATION (LDI)

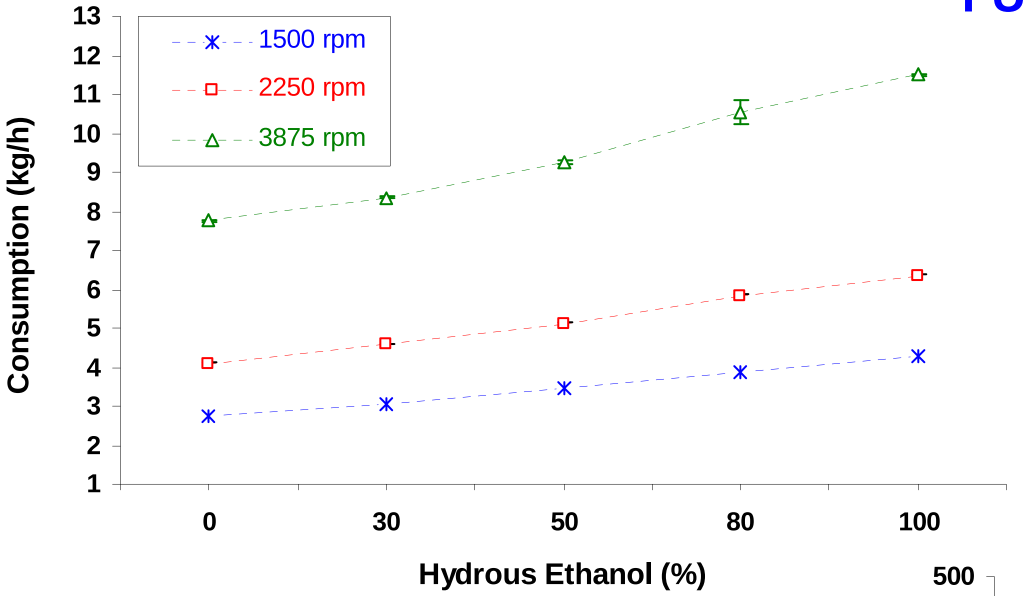


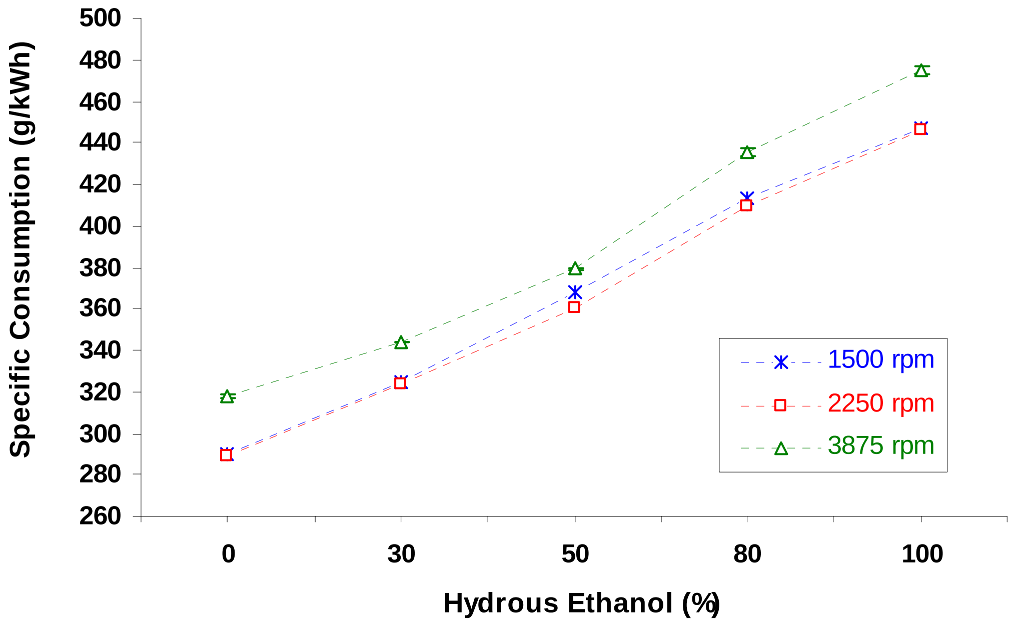


H2O
21
20
19
18
17
16
15
14
H2O (%)
0
30
50
80
100
Hydrous Ethanol (%)
1500 rpm
2250 rpm
3875 rpm

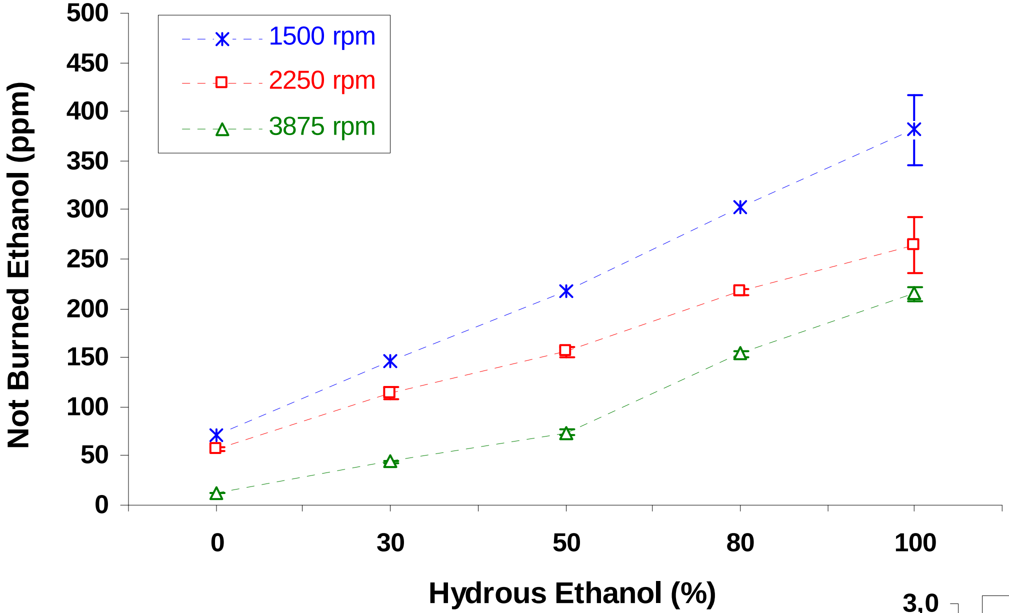
FUEL CONSUMPTION

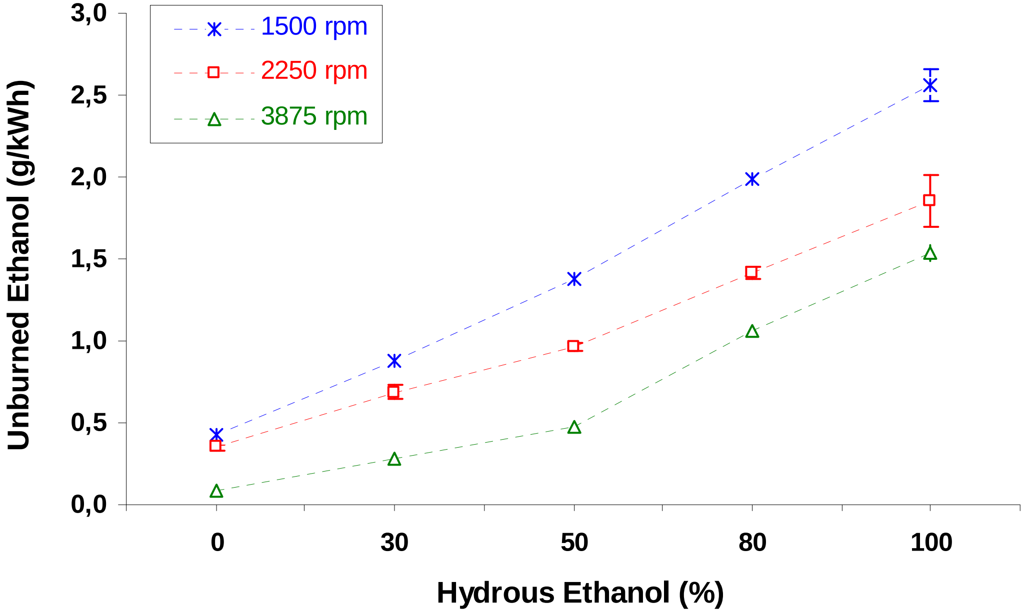
- **ETHANOL HAS A MUCH LOWER LHV THAN GASOLINE, LEADING TO HIGHER FUEL CONSUMPTION**



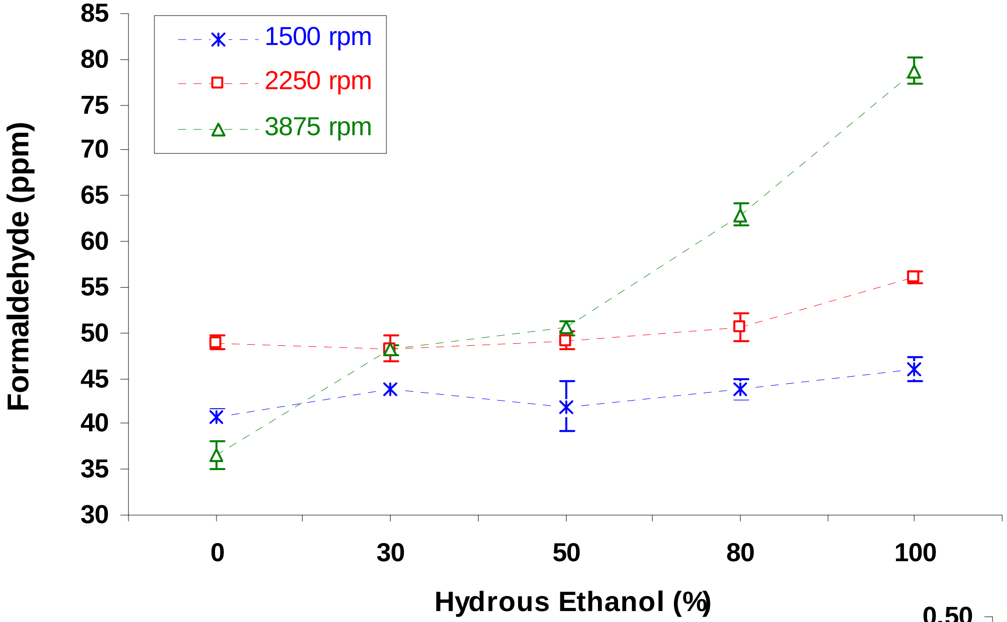


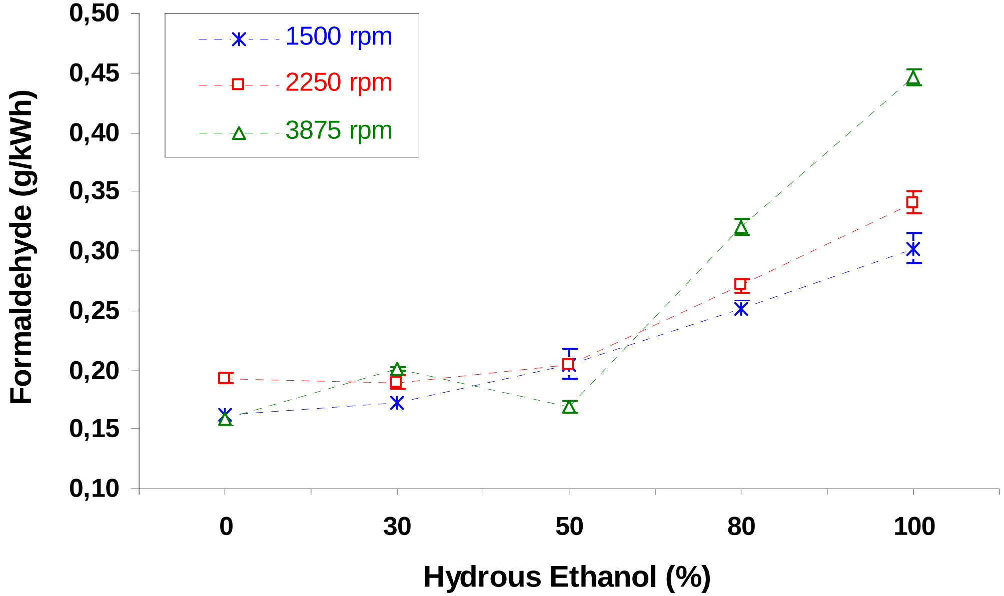
UNBURNED ETHANOL



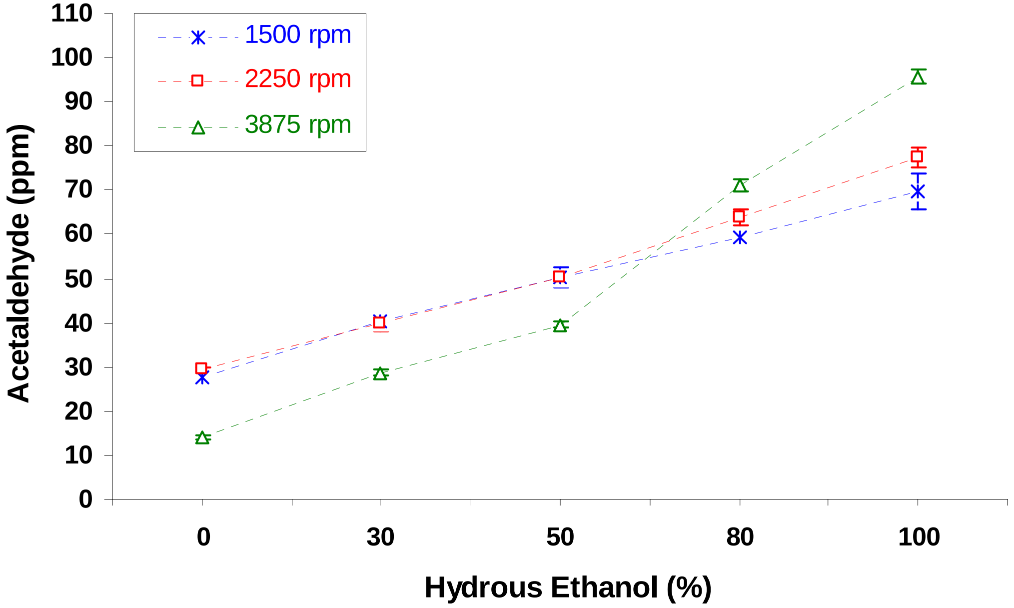


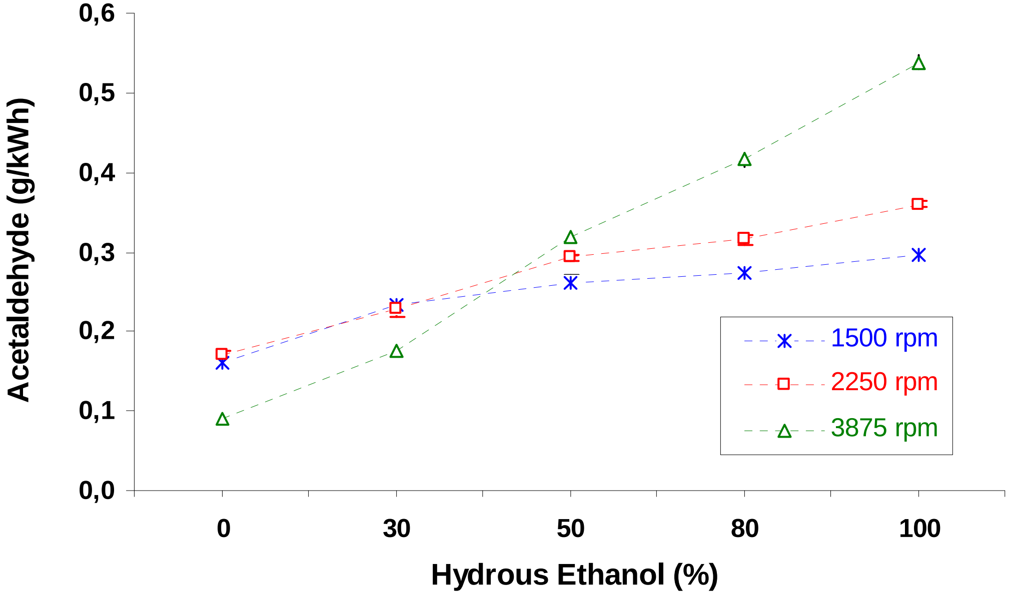
FORMALDEHYDE





ACETALDEHYDE





FINAL COMMENTS:

- ✓ **FTIR proved to be a usefull equipment for measuring ethanol, HC and aldehydes with good repeatibility data.**
- ✓ **THC and CO: reduced with ethanol increase (according to literature).**
- ✓ **NOx: depends on spark timing (chamber temperature). Adding ethanol reduces NOx due also to lower N2 availability (lower A/F).**
- ✓ **Fuel data presented in this paper are not easily found in literature and can be usefull for FLEX-FUEL studies.**
- ✓ **These data are being used to validade emission models of 2 PhD projects (UFRJ and UFMG).**