A MWM D229-6 DIESEL ENGINE CONVERTED INTO AN ETHANOL OTTO CYCLE ENGINE USED IN ACTIVATING ELECTRICAL GENERATOR

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Abstract. *Brazilian sugar and ethanol industries are notable for its intensive use of diesel engines serving electrical generators, motor pumps for irrigation, or fleets of trucks and tractors. Considering the savings in fuel costs and the reduction in emissions, some distilleries in the south of the country, have been partially replacing the diesel by ethanol. Whereas most modern engines with electronic injection, do not allow the use of diesel / ethanol mixture, it is understood that the total replacement of diesel by ethanol may not only bring much more economic benefits for companies, but also advantages for the environment. Taking into account this fact, a team from the Laboratório de Inovação of UFPB, LI, developed a simple, functional and low cost technology to convert diesel engines to ethanol. This paper discusses the conversion of a stationary six cylinder diesel engine 66 kW MWM D229-6 to an ethanol Otto Cycle engine having an electronic ignition and fuel injection. The conversion includes the installation of ignition coils, spark plugs, fuel rail, fuel injection valve, phonic wheel, rotation sensors, throttle body with an integrated TPS sensor, as well as an engine control unit, ECU. Using an electrical dynamometer it was possible to evaluate the engine (original and converted) performances, which were connected to an electrical generator of 120 kW. The levels of fuel consumption, noise and gaseous emissions were registered for all the considered power test runs (10 to 57 kW for the diesel engine and 10 to 40 kW for the converted one). It was observed that the performance demonstrated by the converted engine exceded prospects, enabling a reduction in fuel cost by 11 % when the engine operated at the power of 40 kW with compression ratio of 11.5:1. Regarding to the noise level it was reduced from 101 dB (original engine) to 93 dB. All the gaseous emissions were within the acceptance limits established by the National Council on the Environment, CONAMA.*

Keywords*: Ethanol, Diesel, Electrical Generators, Electronic Ignition and Fuel Injection.*

1. INTRODUCTION

Brazilian sugar and ethanol industries are well known for their intensive utilization of diesel engines used in electrical generators, motor pumps for irrigation, or fleets of trucks and tractors. A research carried out in São Paulo, Brazil, determined that 55% of the state rural irrigation is powered by diesel engines (Marques, Marques and Frizzone, 2006). The use of diesel in a medium size distillery in the Brazilian Northeast, in 2007, to irrigate 400 ha/day demanded more than R$ 1,724,000.00, i.e. about 23 % of the total fuel cost, while expenses to fuel the trucks were 28 % (PoloBio, 2008).

Chiefly in some sugarcane distilleries in São Paulo, the ethanol has been used as renewable and economical alternative to diesel, when just it production cost is considered. For more than ten years a fleet of truck sat São Martinho plant, in Pradópolis, S. Paulo, which consumes 100 thousand liters of diesel mixed with 10% of anhydrous ethanol, during the harvest season, promoting fuel economy and pollution reduction (Melo Neto, 2007).

A team from the Laboratório de Inovação of UFPB, LI, manage to convert the diesel engine into a 100 % ethanol Otto cycle one, after having succeeded to convert different engines to run either with Natural Gas (Rumão, 2008) or with Liquefied Petroleum Gas (Oliveira, 2009).

This paper discusses the conversion of a stationary six cylinder diesel engine 66 kW MWM D229-6 to an ethanol Otto Cycle engine having an electronic ignition and fuel injection. The conversion includes the installation of ignition coils, spark plugs, fuel rail, fuel injection valves, phonic wheel, temperature, pressure and rotation sensors, as well as of an engine control unit, ECU.

From the experimental data was possible to analyze and compare energy efficiencies, fuel costs, gaseous emissions and noise levels of both original and converted engines.

2. THE CONVERSION PROCESS

Before converting the six-cylinder diesel engine MWM D229-6 into ethanol engine, a thorough test is made to determine the diesel consumption in function of the generated power (kW), as well as the gas emissions and the engine noise level. For this purpose the engine was connected to a 120 kW generator and to a resistive load simulator, having control panel and resistor bank modules. Complementing the experimental apparatus there were: a notebook; an electronic scale, a decibel meter and a gas analyzer. In all the tests the engine rotation was fixed at 1800 RPM.

In the conversion process all the engine components related to the diesel circulation system as pipes, pump, diesel fuel injectors, etc., are replaced by the typical elements of an Otto Cycle, such as: ignition coils, spark plugs, spark plug wires, and so on (Taylor, 1968 and Heywood, 1995). An electronic ignition and injection control system comprising a programmed engine control unit, ECU, fuel injectors, fuel common rail, throttle body with throttle position sensor, phonic wheel and crank sensor gap, and an electric fuel pump were also introduced (RacePro-1Fi, 2005).

One of the main tasks in this conversion process is to set a new compression rate adjusted to the ethanol, without inflicting any modification on the pistons.

The ECU was configured in such a way so that the engine would run with multi-point simultaneous fuel injection, firing all four injectors at the same time. To help the unit to set a mixture close to the stoichiometric, a manifold air pressure sensor and a lambda probe at the exhaust system were used. In addition for ignition timing, the waste spark system was chosen and the ignition advance angle was set at 20 degrees.

The converted engine was evaluated under similar conditions as those used in the diesel engine tests, which comprised: analyses of the exhausted gases (HC, CO and CO_2); a thorough investigation about the engine performance, including the determination of their maximum power limits, as well as their fuel consumption curve, as a function of the generated power. Two compression ratios (CR) were taken into consideration when the converted engine was checked, i. e., 11.5:1 and 12.7:1. Figure 1 shows the whole apparatus used to test the engines.

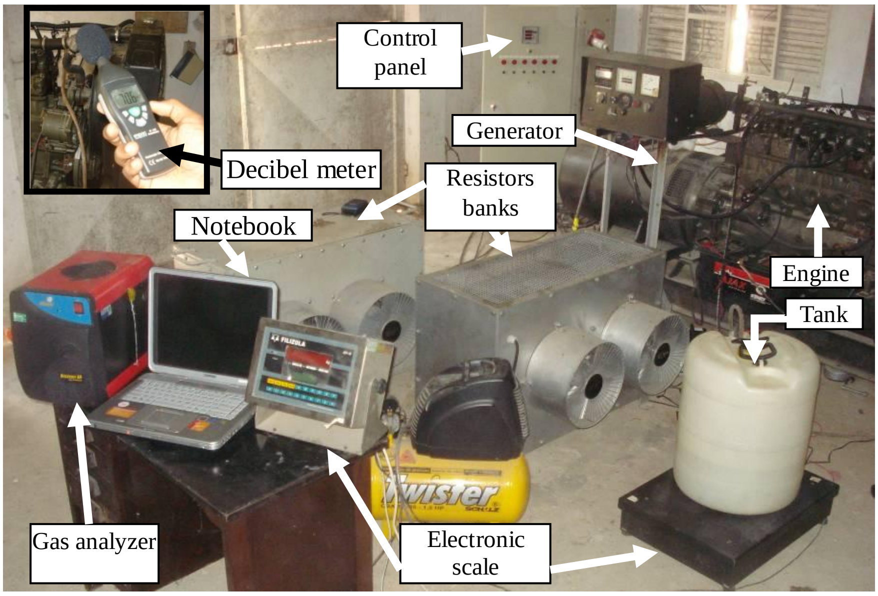

Figure 1. Set of equipment used to test the MWM D229-6 engine.

3. RESULTS

Figure 2 shows the experimental fuel mass consumed behavior in function of the generated power, concerning the original diesel engine and the converted one. For the converted engine two compression rates were examined: 11.5:1 and 12.7:1.

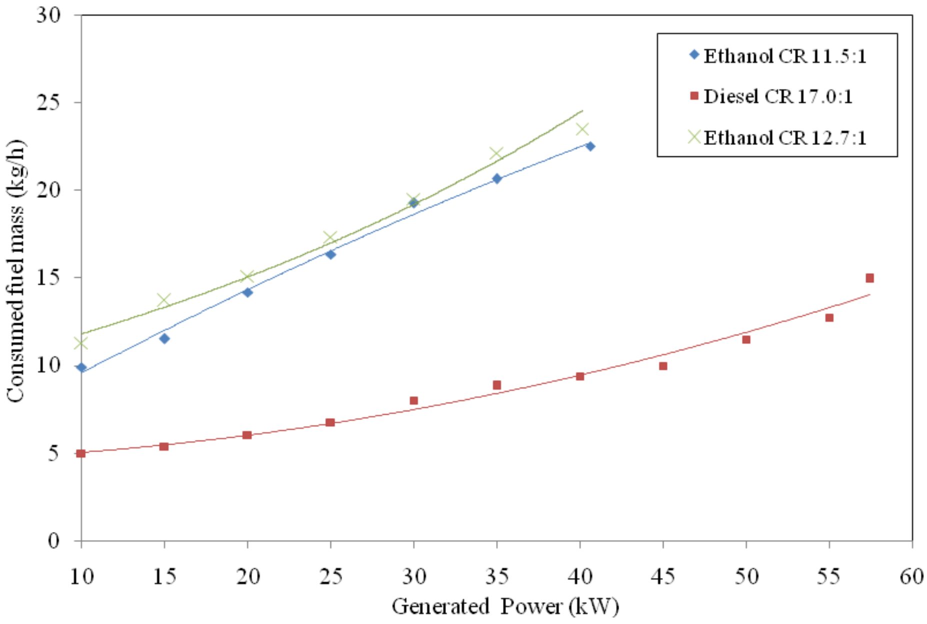

Figure 2. Consumed fuel mass by Diesel engine and converted to Ethanol in function of the generated power (the ethanol data are expressed in terms of CR11.5:1 and CR 12.7:1).

Figure 3 shows fuel costs in function of the generated power. To plot Figure 3 curves, the following parameters: the consumed fuel mass during the tests (see Fig. 2) and characteristics of fuels (see Table 1).

Table 1. Characteristics of diesel and of ethanol.

	Specific mass (kg/m³)	Lower heating value (MJ/kg)	Cost (US$/liter)
Ethanol	810.0	24.92	0.42
Diesel	842.4	43.96	1.26

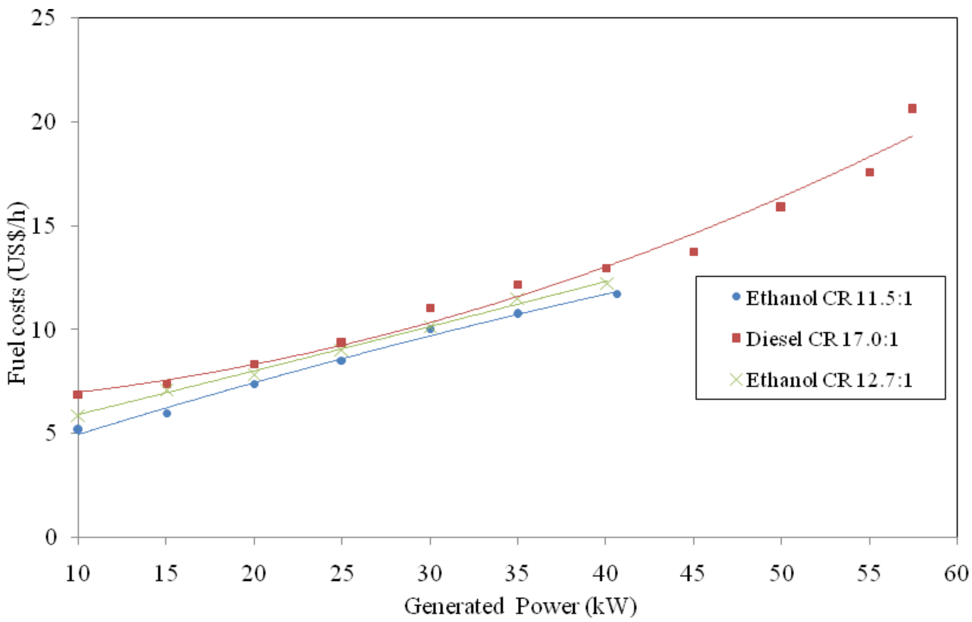

Figure 3. Fuel costs (by Diesel and by Ethanol) in function of the generated power.

Figure 4 shows the reduction (%) in fuel cost in function of the power generated when diesel engine is replaced by the ethanol converted one (CR 11.5: 1).

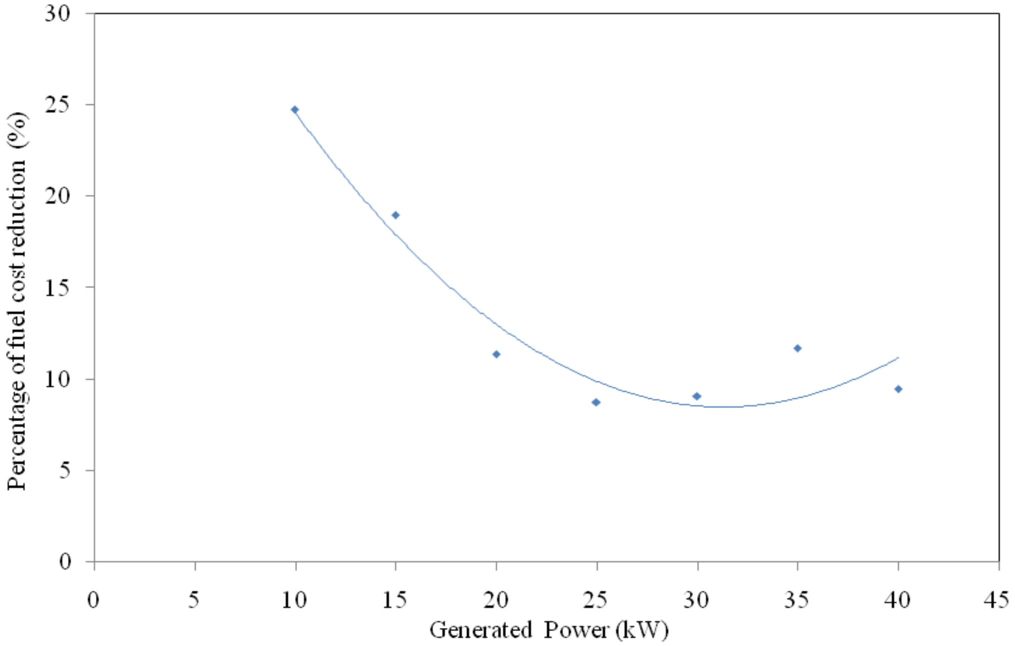

Figure 4. Fuel cost reduction (%) in function of the generated power.

Figure 5 presents the emissions of hydrocarbons produced by the converted engine (CR 11.5:1), in function of the generated power.

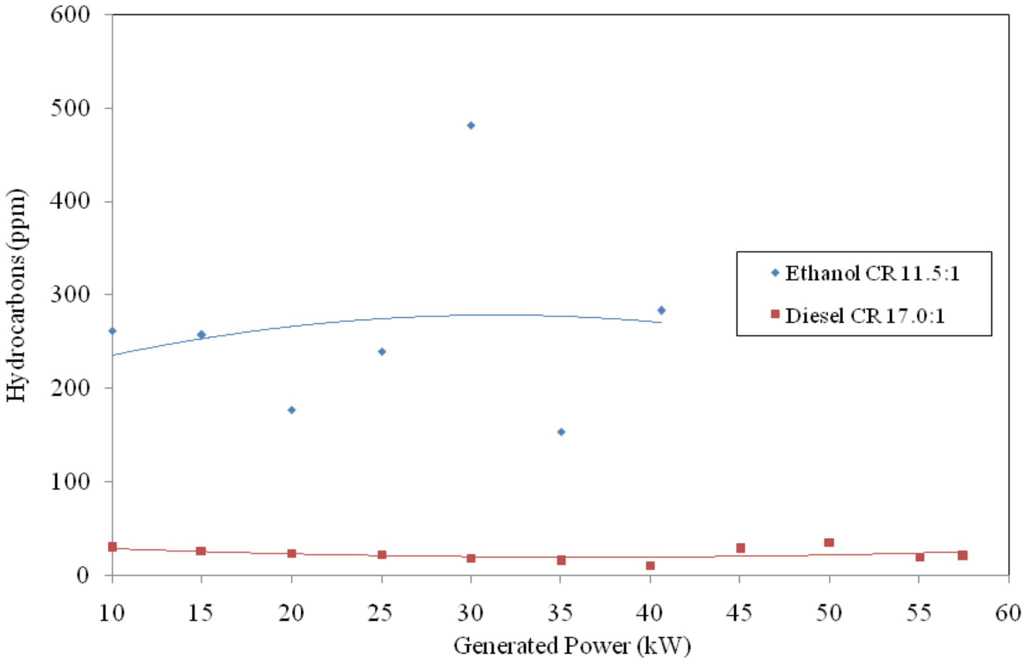

Figure 5. Hydrocarbons emissions produced by the converted engine (CR 11.5:1) and by the diesel one in function of the generated power.

In Figure 6 can be seen the percentage of corrected CO produced by the converted engine (CR 11:5:1) and by the diesel engine, in terms of generated power.

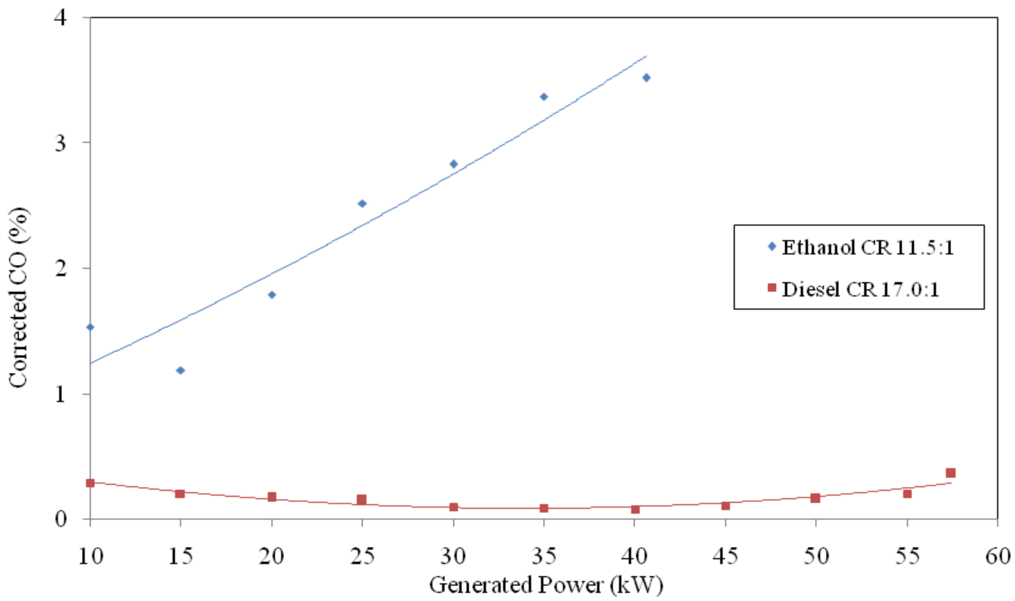

Figure 6. Percentage of corrected CO produced by the converted engine (CR 11.5:1), in terms of generated power.

The dilution percentage behavior related to the converted (CR 11.5:1) and the diesel engines, in function of the generated power is shown in Fig. 7.

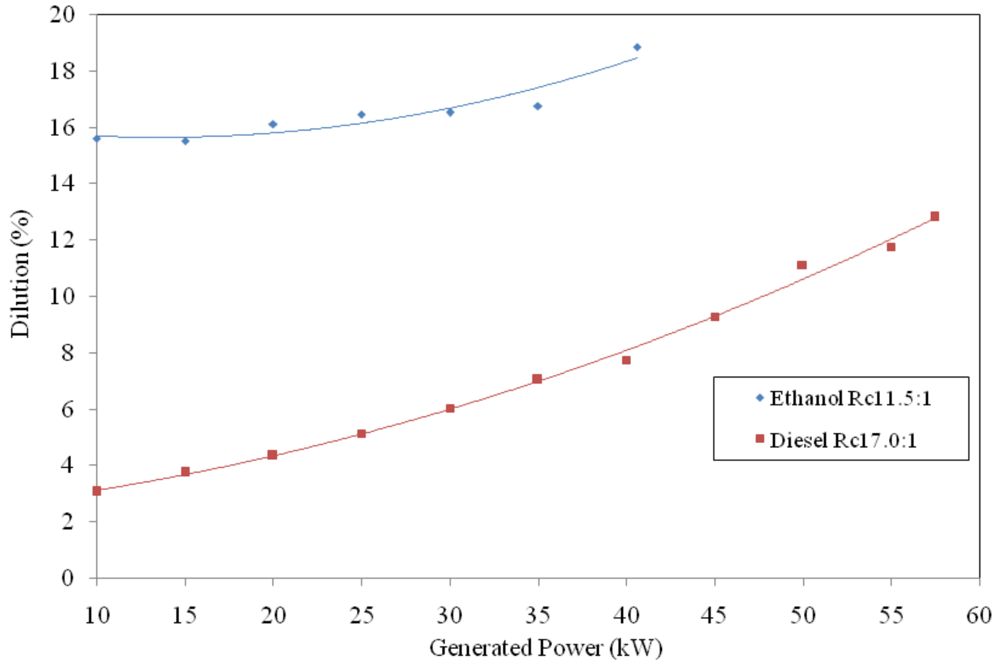

Figure 7. Dilution percentage related to converted engine (CR 11.5:1), and the diesel one, as a function of the generated power.

Figure 8 shows the levels of noise produced by the diesel engine and the converted one (CR 11.5:1), in terms of the generated power.

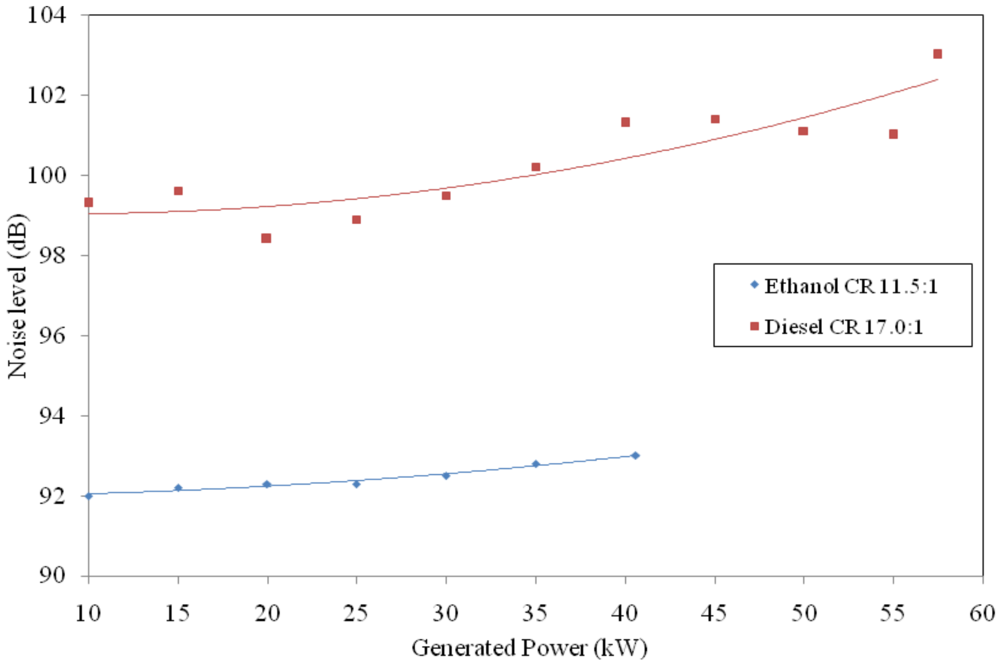

Figure 8. Noise level (dB) emitted by the converted engine (CR 11.5:1), and the diesel one, as a function of the generated power.

4. CONCLUSION

The compression ratio of 11.5:1 allowed the engine to achieve a lower consumption for the compression ratio of 12.7:1 (see Fig. 2). The fuel cost reduction from just the fuel switching maybe situated between 9 to 25 %, depending on the generated power, for the engine operating at a compression rate of 11.5:1 (see Fig. 3).

A restriction involving the replacement of diesel by ethanol is related to its calorific value, which is about 62 % of that of the diesel. This factor contributed to the reduction of the maximum generated power by the converted engine observed in tests (Diesel, 57.5 kW and Ethanol, 40.6 kW). However, considering that in most industrial applications the diesel engines, that activate generators or pumps, operate as 70 % of its maximum capacity, the mentioned difference does not affect the replacement effectiveness in any significant degree (should be noted that at 40 kW has been a fuel cost reduction by 11%).

The ethanol engine, basically, does not emit particulates, nor NOx, or SOx pollutants, which characterize the diesel combustion. On the other hand, concerning HC and CO emissions and the minimum dilution threshold (see Figs. 5 to 7) all are within the limits established by Brazilian Council on the Environment CONAMA (HC maximum, 1100 ppm, CO corrected maximum, 5 %, and the minimum dilution threshold 6 %). Therefore, the converted engine, may contribute to the reduction of the environmental pollution.

As regarding the noise, was observed a maximum reduction of 101 to 93 dB in 40 kW (see Fig. 8), taking into account the difference between the noise emitted by the diesel engine, and the one produced by the converted engine. Such reduction contributes to increase the exposure of the employees at the work, where the diesel engine was replaced by an ethanol one.

In the conversion of engines it is of paramount importance that some aspects concerning the functionality, reliability, price, maintenance costs, emissions in accordance with environmental laws in Brazil, and fuel cost reduction due to fuel replacement, are observed. Field tests, have proved that all converted engines showed high performances and durability, unquestionable ability to perform similar tasks as the diesel, over an appreciable period of time, needing less maintenance and requiring less expenses to handle the ethanol.

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