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# DESIGN OF A MECHANICAL DEVICE FOR REDUCING NOISE AND ISSUANCE OF GAS AND PARTICLES FOR DIESEL ENGINES FROM AN ENERGY GENERATING ENGINE.

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***Abstract.*** *The generation of local electric energy has been a growing concern on the part of large companies or isolated localities. This fact occurs for several reasons, either to avoid a high electric energy tariff at certain times, or to provide electricity to an isolated community or to decentralize the Brazilian energy matrix in which, historically, hydroelectric plants predominates, which Is subject to events that escape human control as a sudden drop in the reservoir water level. To supply this need, the use of diesel generator sets is a very practical option. However, these equipments, especially when grouped in thermoelectric plants, usually generate high levels of noise as well as a high emission rate of particles and pollutants in the atmosphere, both in many cases, outside the established norms and environmental standards for such activity. Considering the current environmental situation, in which there is a special concern with the accumulation of pollutants in the air, this work proposes to expose the results obtained from an innovative device, which have the purpose of purifying the exhaust gases of diesel generators, as well as reducing the level of noise emitted in the exhaust line. The device is compact and easy to maintain, based on the principles of industrial gas scrubbers and mufflers. This unprecedented device operate with the use of a fluid responsible to separate solid particles from the harmful gases into the environment, reducing particulate emissions, while its geometry should reduce the energy contained in the sound waves from the combustion engine.*

***Keywords: :*** *noise level reduction, exhaust gases purifying, particles matter reduce*

## 1. INTRODUCTION

Historically, Brazil's energy matrix is dominated by generation from hydropower sources. This is due to the fact that, according to the studing of Eletrobrás 2015, Brazil is the country with the highest hydroelectric potential, with a potential of 260 thousand MW. This factor has led to the emergence of numerous small, medium and large hydroelectric plants, which are essential to maintain the continuous supply to homes and industries. In addition to the abundance of water resources in the country in question, another factor that leads to a predominance of power generation from hydropower is an efficiency with a quality of energy, since most of the functioning hydraulic turbines yield much higher when compared to other forms of power generation.

Despite the large generation capacity, Brazil still faces energy crises. This fact occurs due to the country's dependence on water resources, so that when there is a shortage (during times of drought, for example), the hydroelectric power generation capacity and efficiency are compromised. Considering the problem of centralization of the energy matrix, the energy supplied by the concessionaires was no longer reliable, which led companies and establishments to seek alternative sources of energy, so that activities could be maintained in the event of insufficient supply, one of these alternatives is the use of diesel generator engine. According to data from the National Electric Energy Agency (ANEEL), see Tab. 1, it is possible to note the relevance of hydroelectric energy and how thermoelectric energy, also, has a wide use in the Brazilian energy matrix.

Table 1 - Energy production data provided by ANEEL

| Operating Undertakings | | | | |
|---|---|---|---|---|
| **Type** | **Quantity** | **Power Grant (kW)** | **Controlled Power (kW)** | **%** |
| **HGP** | 617 | 558.544 | 561.000 | 0,36 |
| **WPG** | 465 | 11.409.639 | 11.366.443 | 7,38 |
| **SHP** | 431 | 4.970.991 | 4.955.175 | 3,22 |
| **PSPP** | 59 | 356.248 | 298.184 | 0,19 |
| **HP** | 219 | 101.169.128 | 93.858.334 | 60,9 |
| **TNE** | 2.929 | 42.474.522 | 41.083.557 | 26,66 |
| **TEP** | 2 | 1.990.000 | 1.990.000 | 1,29 |
| **Total** | **4.722** | **162.929.072** | **154.112.693** | **100** |

OBS: The percentage values refer to Supervised Power. The Granting Power is equal to that considered in the Granting Act. The Supervised Power is equal to the one considered from the commercial operation of the first generating unit.

Subtitle: HGP: Hydropower Generating Plant; WPG: Wind Power Generator; SHP: Small Hydropower Plant; PSPP: Photovoltaic Solar Power Plant; HP: Hydroelectric Plant; TEP: Thermoelectric Plant; TEP: Thermonuclear Plant.

Barros (2009) points out that the use diesel generators has gained momentum since the "blackout" occurred in 2001. These machines appear as a practical solution serving isolated communities, rural producers, industrial and commercial sectors. These motors are dimensioned according to the customer's need so that it can be used as an alternative energy source to avoid high tariffs at peak times and can still be used to maintain supply in the event of a power outage or as the sole and primary source of a community.

Large urban centers face various problems related to atmospheric pollution. The effects in health are caused of high concentrations of pollutants have been the subject of a warning from the World Health Organization (WHO, 2015), which recently issued a global report on urban air quality with particularly worrisome data on inhalable particulates.

Particles in the atmosphere may have anthropogenic origin such as those emitted in industrial processes, burning of fossil fuels, burning of biomass among others, while particles of natural origin are related to a variety of processes that include volcanic emissions, wind transport of particles from the earth's crust and the oceans (Seinfeld and Pandis, 2006).

In this context, there is a need to develop studies capable of mitigating the disadvantages related to diesel generator sets, therefore, this work proposes a presentation of an innovative device capable of reducing the emission of liquids, the level of noise coming from of the exhaust system of diesel engine generators.

## 2. EXPERIMENTAL PROCEDURE

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The engine studied was the diesel generator set model YANMAR - 4TNV GGE of 20 kVA. The engine is located in the Motors Laboratory of the Federal University of Pará and is a tool widely used by students during diesel engine repair courses, differentiated fuel tests and general classes. In this engine were obtained data on the exhaust gases and the noises generated in their vicinity where, daily, there are people working.

The fuel used to perform the tests was B7 (conventional diesel mixed with 7% biodiesel).

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### 2.1 Noise analysis

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For the analysis of noise was used the Dosimeter of the manufacturer 3M model SE-400 IS as shown in Figure 2.

Figure 2 Dosimeter SE-400 IS.

Measurements occurred in two moments, the first with the SL-355 Dosimeter without the device is installed in the motor and the second with the device already installed the dosimeter SE-400 IS, but without the injection of water.

The dosimeters were positioned one meter high from the ground, one meter away from the engine (in the front portion and so as not to be disturbed by the displacement of air caused by the radiator) and at least one meter away from any other obstacle as recommended by the ABNT NBR 10151 standard.

The equipment was then configured to perform measurements in the range of 60 to 130 dBA for a period of five minutes.

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## 2.2 Water pressure and flow

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To determine the maximum water pressure and therefore the maximum flow rate that can be injected into the DRGR without the water entering the exhaust manifold, we perform the following procedure:

With the DRGR out of the engine leaning on a structure as shown in Figure 3, we connected the hose and gradually increased the pump rotation through the inverter until water started to flow through the tube that connects the DRGR to the engine. Through the manometer we measured the pressure of the system at that moment and varying the frequency from 5 in 5 HZ to 60 HZ. Figure 4-a shows the manufacturer's C.BORDALO manometer used to measure line pressure and Figure 4-b shows the FLOWPET-EG flowmeter from the OVAL model LS4976-430A.

Figure 3-a manometer

Figure 4-a manometer

Figure 4-b flowmeter

## 2.3 Gas meter

The data concerning the pollutant content in the exhaust of the engine studied were obtained with the aid of a portable analyzer model Optima 7 manufactured by MRU Instruments as shown in Figure 5.

Figure 5- Optima 7 portable analyzer manufactured by MRU Instrument

The load applied to the stationary motor was 100%. After the engine was started, it took thirty minutes to stabilize it, and then the gas analyzer probe was introduced to perform the reading. The noise reduction device, the gases and the particulate material were then added and the motor was tested again under the same operating conditions. It is noteworthy that the probe was inserted in a hole about 0.70 m away from the exhaust manifold.

### 2.4 Opacity meter

For the measurement of opacity the Smoke Check 2000 Portable Opacimeter from the manufacturer Altanova shown in Figure 6 was used.

Figure 6- Opacimeter Smoke Check 2000

The gas flow after passing through the device is directed out of the bay by a tube and at the tip of the tube the opacity measurement is made. The probe of the opacimeter is inserted into the whole and remains for five seconds and then removed and repeated at least 3 more times until the difference between the last three measurements does not exceed 0.5 m -1, then the result is printed on the opacimeter it-self.

### 2.5 Temperature measurement

The temperature measurement was done using K type thermocouples, installed in the gas inlet and outlet and in the water inlet and outlet, as shown in Figure 7.

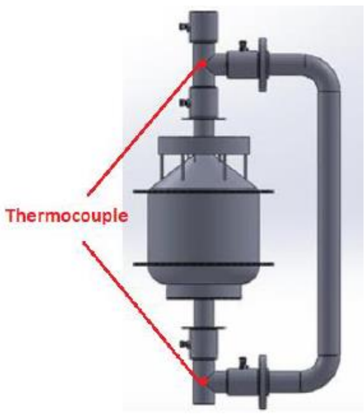


Figure 7- Position of type K

The thermocouple probe, see Figure 8, sends electrical signal to the A202 data seeker, see Figure 9, which enables the recording and monitoring of the analog variables in a computer, it captures the data of the thermocouples installed in the device and converts a signal into the which the computer can acquire.

Figure 8- Position of type K

Figure 9- Data Acquisitor A202.

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## 3. PROCEDURES AT THE PLANT

The device was built by the company ABC Parts, in partnership with the researchers of the Federal University of Pará, according to the characteristics determined from field surveys in thermoelectric plants, laboratory tests and computer simulations.

### 3.1 Installation Location

Mitsubishi engine exhaust pipe above the expansion joint, as shown in Figure 10, which shows the location of the DRRG installation in place of the engine noise attenuator.

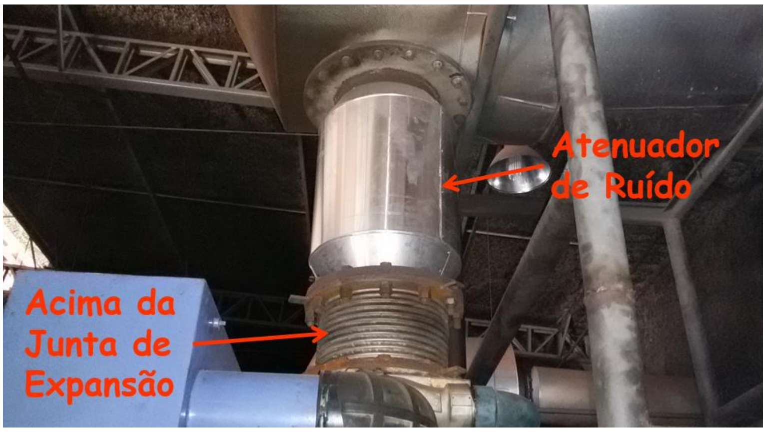


Figure 1. Device installation location.

### 3.2 General features

Weight: 450 kg (without water);
Diameter: 1190 mm (in the body) and 1400 (with the side rings);
Length: 1000 mm (from flange to flange);
Material: carbon steel;
Water Injectors: 12 Nozzles 1/8 BHM 2.8W NPT in brass;
Dust Collector: Must be constructed with Ø1 1/4 "flexible tubing;
Working temperature: up to 600 ° C (maximum temperature supported by the ink);
Application: Mitsubishi Diesel Cycle Engines;
Volumetric flow rate: up to 10 m3 / s;
Maximum pressure: 13.8 hPa

### 3.3 Procedures for Operating the Device in the Engine.

After the DRRG has been installed in the engine exhaust pipe, the engine test must be performed by the following steps:

1º Step - Engine operation: The device has been developed in such a way that there are no restrictions caused to the engine during its operation, so the engine must be put into normal operation, because with the DRRG installed in the exhaust pipe, there must be no changes in the engine operating procedures.

Check for gas leaks in the DRRG flange fittings.

When starting the engine, make sure that the water inlet and dust collector outlet registers are closed.

Note: During the first engine starts it is possible that there is a large amount of smoke produced in the body of the device, because in the interior and exterior areas of the DRRG a high temperature paint is used which must be conditioned to the engine operating temperature.

2º Step - Synchronization: After the ramp up, where the nominal motor conditions are reached, the motor must be synchronized with the local power grid, after which the actual motor operating load must be adjusted.

3º. Step - Water Injection: After the effective engine operating load is reached, the DRRG control and water injection register must be slowly opened and adjusted by controlling the line pressure.

During the operation, the dust collector register must be slowly opened and it must be observed if a water leak is occurring. If this occurs, the water inlet register must be regulated, reducing the flow rate, so that only dust (particulates) may leak into the dust collector.

4º. Step - Check dust: at each hour of operation, open the dust collector register of the DRRG in order to release the dust generated during the operation of the motor.

5º. Step - Removal of operation: After the period of operation of the motor has finished, one must make sure that the register of the dust collector is closed. The water injector register on the DRRG of the engine should be closed.

6º. Step - Motor stop: The motor descent ramp must be carried out in order to remove it from operation.

## 4. RESULTS AND DISCUSSIONS

**In the Lab**

### 4.1 Device for the Reduction of Noise and Emission of Gas and Particles (DRNP)

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The device consists of an outer casing made of light material, resistant to corrosion and high temperature, water spray nozzles, particulate collecting tray, sound wave dissipation screen, internal curves to increase the agglutination efficiency of solid particles two gases and flared holes for exhaust gas inlet and outlet.

The gas flow from the fuel burn in the engine will be directed to the engine exhaust manifold and to the DRGR. Still in the "gas inlet" tube of the DRGR there is a metal screen with small holes which has the duty to attenuate the sound waves coming from the passage of gases through the exhaust pipe of the engine. The gas then flows through the curves within the zig-zag device.

Upon entering the DRNP the gases will run through the profile of the geometry in the first passage, in the upper area of the equipment, in the same direction of the flow of gases, water is sprayed so that a mist is formed inside the device. The water particles should promote agglutination of the particulate material of the engine such that when these agglutinated particles reach sufficient size and mass they will decant by gravity and settle into the particulate collecting tray located in the lower portion of the DRNP.

The DRNP should be installed after the engine expansion joint, which has a vibration in its operation. This vibration will lead, through an aperture located in the same region, the excess agglutinated particulate within the DRNP, which will be removed to a dust deposit located in the lower region of the equipment.

The exhaust gases are then conducted to a second passage within DRNP where the gas flow will have the opposite direction to that of the water spray, performing a second gas flushing and noise attenuation. With the counterflow the exhaust gases the DRNP will potentiate particulate removal and noise reduction.

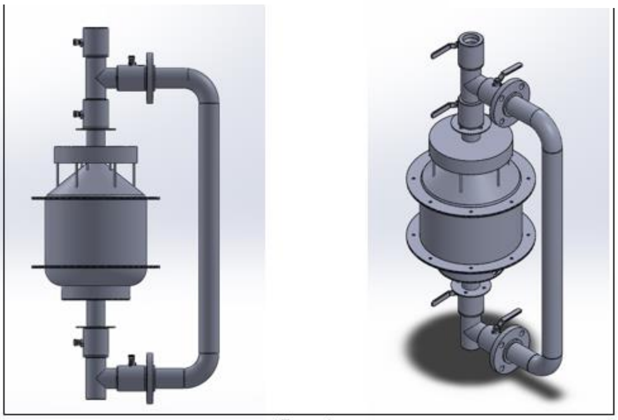
The device works similar to a gas scrubber in which it uses water to flush the combustion gases within the engine, and similar to an automobile silencer, in which it attenuates the exhaust fumes, but performs these tasks in a single metal housing designed specifically for these purposes.

Figure 10 shows the DRNP in the current stage, where it can be observed that the bypass was developed, which is nothing more than a direction of the gas flow outside the device. To measure with the Opacimeter, the "C" structure of the by-pass is removed by a straight pipe at the top, thus directing the flow of gas out of the bay horizontally, and at the point of the tube is measured the opacity of the gas flow.

Figure 11-A shows the device installed in the motor. Its installation was made on top of the vibration damper that connects the exhaust manifold to the exhaust pipe. The main caution was in relation to the device not to put all its weight on top of that damper, which could cause the exhaust manifold to break. The solution found was to hang the device by steel cables on the steel beam that passes over the bay. This detail of the hanging device with steel cable can be seen in Figure 11-B.

Figure 11-A- Device installed in the motor.

Figure 11-B- Installation details device with steel cables.



## 4.2 Noise Reduction Analysis

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Table 1 shows the results obtained with a noise data collection. They were made as measurements for the group generating load and with as cars of 30%, 50%, 70%, 90% and 100%.

Table 1. Sound power obtained during the tests in the diesel engine, with and without the DRNP device, for different applied loads.

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| Motor Load Percentage | Sound Power Without DRNP | Sound Power with DRNP without water Injection | Percentage of Sound Power Reduction | Reduce (dBA) |
|---|---|---|---|---|

| | (dBA) | (dBA) | | |
|---|---|---|---|---|
| **No charge** | 95,9 | 87,40 | 8,86% | 8,5 |
| **30% load** | 95,7 | 89,15 | 6,84% | 6,55 |
| **50% load** | 95,6 | 88,45 | 7,48% | 7,15 |
| **70% load** | 95,8 | 88,40 | 7,72% | 7,4 |
| **90% load** | 95,4 | 87,95 | 7,81% | 7,45 |
| **100% load** | 94,8 | 87,00 | 8,23% | 7,8 |

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With the DRNP the noise stabilizes around 87 to 88 dBA. According to regulation 15, the noise level acceptable for workers with a working day equivalent to 8 hours is 85dBa, that is, even with the reduction achieved with the device, it is still necessary to use ear protectors. Another very important point is that the DRNP decreases 8.5 dBA with the engine running without load and 7.8 to 100% of the load, which is something almost three times the minimum perceived value by man, which is 3 dBA.

### 4.3 Gas Analysis

Regarding the observed changes in the exhaust gases from combustion, Table 2 shows the results obtained without the application of the DRNP, while in Table 3 are the results obtained with the device.

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Tabele 2. Results obtained without the DRNP for the load of 100%

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| CO2max (%) | Gases Exhaustion-T [°C] | air-T [°C] | O2 [%] | CO [ppm/ref0%] | NO [ppm] | NO [ppm/ref0%] | NOx [ppm] | NOx [mg/MJ] |
|---|---|---|---|---|---|---|---|---|
| 15,3 | 416,8 | 33,3 | 9,8 | 494 | 340 | 636 | 357 | 336 |
| 15,3 | 416,5 | 36,1 | 9,8 | 516 | 346 | 647 | 363 | 342 |
| 15,3 | 417,3 | 36,2 | 9,7 | 502 | 344 | 640 | 361 | 338 |
| 15,3 | 417,8 | 37,1 | 9,7 | 492 | 347 | 642 | 364 | 339 |
| 15,3 | 418,9 | 37,3 | 9,7 | 463 | 348 | 644 | 365 | 340 |
| 15,3 | 417,35 | 35,75 | 9,75 | 490,83 | 344,83 | 642,67 | 361,83 | 339,5 |

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Tabela 3. Results obtained with the DRRG for the load of 100%

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| CO2max (%) [%] | Gases Exhaustion-T [°C] | air-T [°C] | O2 [%] | CO [ppm/ref0%] | NO [ppm] | NO [ppm/ref0%] | NOx [ppm] | NOx [mg/MJ] |
|---|---|---|---|---|---|---|---|---|
| 15,3 | 158,2 | 33,9 | 10,2 | 427 | 357 | 693 | 375 | 366 |
| 15,3 | 158,8 | 35,2 | 9,9 | 420 | 347 | 659 | 364 | 348 |
| 15,3 | 158,8 | 35,5 | 9,9 | 420 | 352 | 665 | 370 | 351 |
| 15,3 | 159,4 | 36 | 9,8 | 412 | 352 | 662 | 370 | 349 |
| 15,3 | 159,5 | 36,1 | 9,8 | 406 | 351 | 660 | 369 | 349 |
| 15,3 | 158,83 | 35,23 | 9,93 | 419,83 | 350,83 | 666,67 | 368,5 | 352 |

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Note that the largest changes occurred in the temperature of the exhaust gases and the amount of CO emitted to the atmosphere. The CO reduction was, on average, 14.5%.

It is noteworthy that the gas washing can still be improved, because during the tests it was noticed that a part of the injected water was not being sprayed in the desired way, resulting in a less gas washing.

### 4.4 Pressure and Water Flow Analysis

The device originally had ten spray nozzles, however, as previously tested for water injection out of the engine, it was observed that the amount of water was too large with these ten nozzles thus attempting to enter the engine by the discharge and break the engine. Thus, for this test, only two nozzles were used, considerably reducing the water injection rate.

Selecting a frequency of 30 Hz in the frequency inverter that controls the rotation of the centrifugal pump that injects water into the device, the recorded volumetric flow rate was 189 l / h and an injection pressure of 2 bar.

### 4.5 Opacity Analysis

Opacity was measured without water injection and with an injection, an average of four measurements were made for each. The results are shown in Table 4.

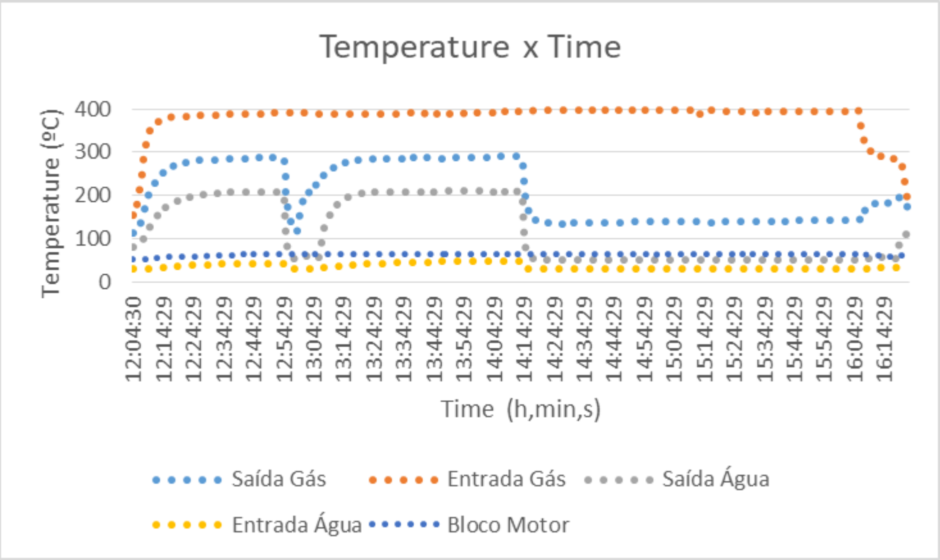
Table 4. Results obtained with the DRRG for the load of 100%

| | **Measured value ( $m^{-1}$)** | **Percentage reduction (%)** |
|---|---|---|
| **Without injection** | 0,36 | 28,5 |
| **With injection** | 0,28 | |

Without water injection the measured value was 0.36 m-1 and with injection the measured value was 0.28 m-1, that is, it heard a reduction of 28.5% reduction of emission of particle material for the atmosphere. The engine is already complying with CONAMA Resolution 418/09 where the maximum opacity limit at a height of up to 350 meters is 1.7m-1, but with the use of the device it reduces this emission even more.

### 4.6 Temperature Analysis

Figure 12 shows the temperatures during the water injection.




From the previous image it is observed that the gas inlet temperature remained close to 400 ºC, which means that in fact there was no water flowing through the exhaust, so the integrity of the engine was maintained.

The water and gas outlet temperatures decreased, with the water output decreasing from just over 200 ° C to about 52 ° C and the gas outlet near 287 ° C to around 141 ° C, which is a very significant reduction to reduce the harmful effects of the emission of the flue gases.

The water inlet temperature and that of the engine block were practically unchanged. This behavior, since the flow of water is constant, has a temperature of around 36 ºC and that of the engine block has no contact with the engine. water and was around 65 ºC

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**At the plant**

The installation process of the device is still being finalized and soon the data will be shown and the analysis will be done in comparison to the determinations in the laboratory.

## 5. ACKNOWLEDGEMENTS

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## 7. RESPONSIBILITY NOTICE

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