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# THERMAL EFFICIENCY ANALYSIS OF A LPG WATER HEATER

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***Abstract.*** *The present paper intends to calculate the thermal efficiency of a gas water heater, observe the heat exchanger with a thermal camera and analyze the results. For the calculation of this value, thermodynamic equations for absorbed thermal energy, provided thermal energy and thermal efficiency equation were used. The tests were performed on a Bosch heater model GWH 250 B GLP / GN AS0ND with an efficiency equal to 80.9% according to the manufacturer. The heater was switched on and, once the temperatures were stabilized, the initial data were collected and 6.5 minutes later the final data were collected. In the first and second tests, yields of 71.92% and 72.17%, respectively, were found. The pictures taken with the camera show areas of high temperature (wasted energy) that could be more used in heating the water. Therefore, it can be concluded that the yield of the heater is somewhat satisfactory, but with much room for improvement.*

***Keywords:*** *Thermal Efficiency, water heating, thermal analysis*

## 1. INTRODUCTION

### 1.1 Heat transfer

Thermodynamics is the science that studies the changes of systems and their related phenomenons. Some of the main variables observed by this area are pressure, temperature and conditions related to the fluid flow of systems. The temperature is, in an elementary sphere, the energy of movement of the particles, bodies with high temperatures have its molecules moving more than bodies with low temperatures (ÇEGEL, BOLES, 2006). A branch of thermodynamics that focuses most on the variations of its greatness is the study of heat transfer. This area studies the transfer of thermal energy in 3 ways: conduction, convection and radiation.

#### 1.1.1 Combustion

Conduction heat transfer is more commonly characterized as the form of heat propagation in solids. In other words, the transfer of thermal energy between adjacent particles in the same body of mass m. One of the most widely used ways to calculate the rate of heat transfer by conduction is nothing more than interpretation of Forrie's Law.

#### 1.1.2 Convection

Convection is the transfer of thermal energy in a system caused by the movement of the particle itself. That is, a particle of matter does not pass its energy to other adjacent to it, but rather moves itself into another position and, trivially, carries with it the energy of movement which it had with it to another location in the system (KREITH,1973). Therefore, this form of heat occurs only in fluids, because the particles that compose it can move around.

#### 1.1.3 Radiation

The thermal radiation is the form of propagation of thermal energy in the vacuum. Also referred to as irradiation, this flow of thermal energy that occurs by means of electromagnetic waves starts from any body with temperature above absolute zero (KREITH,1973). The rate at which energy flows by radiation depends mainly on the emissivity of each body, and this variable is directly proportional to the intensity of the flow of thermal energy transferred. The temperature of the is another important variable to determine your radiated energy

### 1.2 GLP water heater

Gas water heaters are equipment used to provide heat energy released from the combustion reaction of the combustible gas with atmospheric air to the water that one wishes to heat. Usually the water flows in a closed metallic tube which goes around and/or through the heating zone of the equipment.

Equation 1 below is used to quantify the efficiency (η) of the water heater, where Qf is the heat transfer rate for water and Qq is the heat rate supplied for heating, in the case , by the burning of LPG (JUNIOR, 2006).

$$\eta = \frac{Qf}{Qq} \tag{1}$$

## 2. METHODOLOGY

The equipment analyzed is a gas water heater from the manufacturer Bosch model GWH 250 B GLP / GN AS0ND. The ignition of this equipment is electric and produce by 2 batteries of 1,5 V. The heater useful power is of 250 kcal/min according to its manual. The gas used for the tests was the Liquefied Petroleum Gas (LPG) of the University of Fortaleza gas line. However, the pressure of this gas line is approximately 3 bar. Therefore, it was necessary to use a pressure regulator in order for the inlet LPG have the pressure equal to the operating pressure indicated by the manufacturer (28 mbar).

The equipment used for the measurement of volumetric water flow was a Magnetic Multijet Hydrometer, class B and code M4011BN0E manufactured by LAO Indústria. Produced by the same manufacturer, the LPG volumetric flow measurement was performed with a G 1 Gas Meter. Once the system stabilized, the water volume value V1 and the gas volume V2 were recorded after approximately 6.5 minutes of testing. Throughout the length of the tests, the controllers of the water and gas flow were at maximum.

The water temperature was recorded by a thermocouple model MTK-16 manufactured by Minipa, a immersion type probe, placed directly after the water outlet and another one around a meter from the water inlet. Both of the thermocouple measuring end were insert inside the water hose.

## 3. RESULTS

The water inlet temperature T1, the water outlet temperature T2, the water volume V1 and the LPG volume V2 recorded by their respective volumetric meters are shown in Table 1 below. Finally, the water volume variation ΔV1 and LPG volume variation ΔV2 are calculated from the beginning to the end of the test, by subtracting the final volume by the initial volume of each substance.

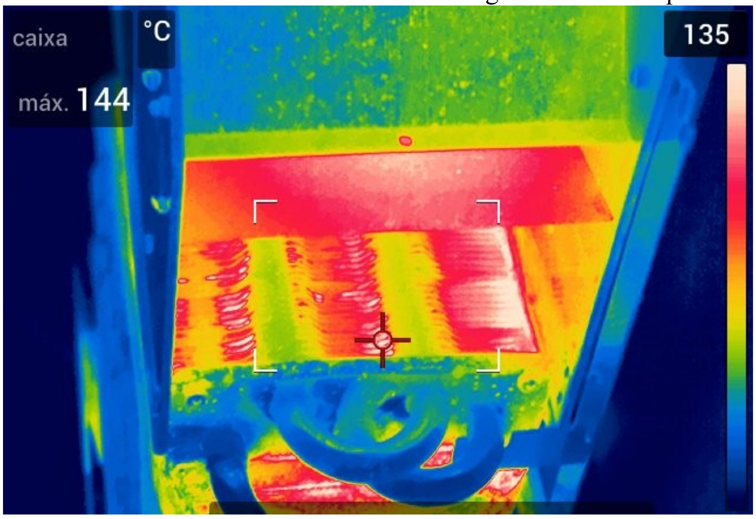
Table 1. Results of temperature and volume from the tests performed in the heat exchanger.

| | **T(min)** | **T1 (K)** | **T2 (K)** | **V1(m³)** | **V2(m³)** | **ΔV1(m³)** | **ΔV2(m³)** |
|---|---|---|---|---|---|---|---|
| **Test 1** | 0 | 300,5 | 324,5 | 0,6828 | 217,4845 | - | - |
| | 6,5 | 300,5 | 324,5 | 0,7215 | 217,5425 | 0,0387 | 0,058 |
| **Test 2** | 0 | 300 | 324 | 0,7327 | 217,5575 | - | - |
| | 6,5 | 300 | 324 | 0,7712 | 217,6150 | 0,0385 | 0,0575 |

Author, 2018

After stabilizing the temperatures recorded, the temperature at the top of the heat exchanger fins was also observed with the thermal camera model E95 from the manufacturer Flir. Below are the pictures recorded by this camera.

Picture 1 - Side view of the heat exchanger at maximum power

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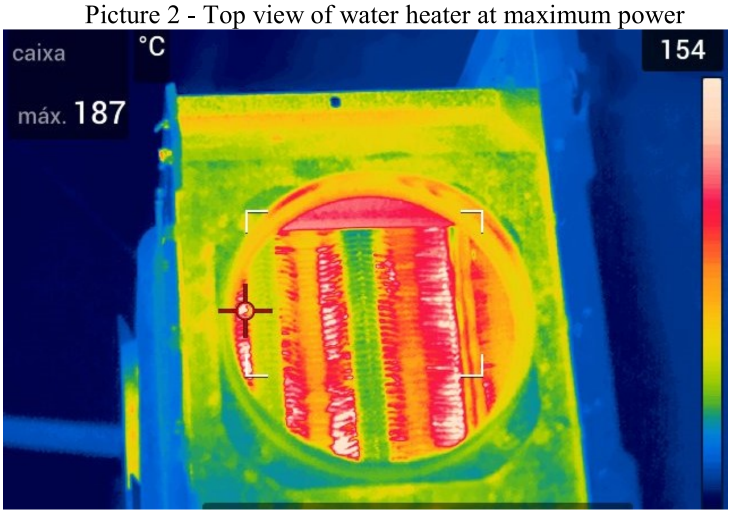
Picture 2 - Top view of water heater at maximum power

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It is observed from the previous photos that the high contrast in the exchangers is evident. This occurs, as shown in Figure 1, due to the water pipe passing through the area of yellow and green tonality.

## 4. DISCUSSION

For the water-related variables used in the yield calculations, the conventional values of 4200 J/kg.K for the specific heat and 1000 kg/m³ for the specific mass were used. Differently from the previous data, the variables related to LPG were obtained by means of a technical report made with a sample of the gas taken from the same line used in the tests. Furthermore, the data of specific mass and lower calorific value of LPG used were 2,068 kg / m³ and 46366,61047 kJ / kg, respectively. To calculate the thermal efficiency, Equation 1 previously shown in subtopic 1.2. The variable Qf is the amount of thermal energy absorbed by the water. This is calculated by Equation 2 below:

$$Qf = cp \cdot m_{water} \cdot (T2 - T1) \tag{2}$$

Where:
*cp*: Specific heat of water [kJ/kg.K];
$m_{water}$: Mass of heated water [kg];
*T2*: Final water temperature [K];
*T1*: Initial water temperature [K].

The mass of both water and LPG were obtained by multiplying their respective specific masses with the volume variation found in Tab. 1.

However, the variable Qq is the amount of thermal energy supplied by the LPG burning and is obtained by Equation 3 below:

$$Qq = PCI \cdot m_{LPG} \tag{3}$$

Where:
*PCI*: Poder calorifico inferior do GLP [kJ/kg];
$m_{GLP}$: Massa de Gás Liquefeito de Petróleo [kg].

Two tests were performed and after the application of the previous equations, the following efficiency were found: 71.92% and 72.17%. The efficiency indicated by the manufacturer of the heater is 80.9%, thus, a discrepancy is found between the values found and the indicated nominal value.

## 5. CONCLUSION

We can attribute part of the non-compatibility of the yield values to withdrawing the fins of the heater’s exhaust gases, made to better visualize the process of heat transfer with the aid of the thermal camera. It is also expected that there will be variation between the result and the tabulated value due to possible variation in the composition and therefore in the variables related to LPG and water.

In addition, it can be concluded from the Pictures 1 and 2 previewly presented that there are high temperature zones in the heat exchanger fins which could be better utilized to heat the water, increasing the absorption of heat from the water without the need for increased gas consumption, thus improving the heater’s efficiency.

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## 7. RESPONSIBILITY NOTICE

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