CONVERSION METHODS FOR COMMERCIAL STOVES FROM LPG TO NATURAL GAS FIRING

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***Abstract**: This paper presents the results of an experimental study of LPG and NG cook burners performance considering the thermal power, gas consumption, and efficiency as a way to establish a technically correct method of cook burner conversion according to the Brazilian standardization standards. A conversion method from LPG to NG cook burners obtained keeps the thermal equivalence between the two fuels for wok commercial stoves. The experimental study was carried out following the ABNT NBR 13723-1,2:2003, and NBR standards, and the LPG cook burner tests were carried out according to the Asian food commercial restaurants usually way adopted (high pressure operation).*

***Keywords**: Energy conversion, Stoves, Cook burner, LPG, Natural Gas.*

1. INTRODUCTION

Asian food style preparation requires fast and high cooking temperature. Common or low pressure wok cooking burner using LPG (Liquefied Petroleum Gas) or NG (Natural Gas) does not have sufficient thermal power to supply enough fuel to meet that requirement. Some restaurants have been using a dangerous practice of using LPG cook burners directly plugged to the LPG tank in which, at temperature level of 293 K, gas is stored at approximately 700 kPa. The only security device is a needle valve generally used for fire control. It represents a highly dangerous operational condition because, whether a leak or an accident occurs, all LPG gas can flow out from the tank to environment in a short time given rise to a potentially explosive cloud. A not technically investigated but usual market solution for that problem is to use special NG burner ("Duck Bill Burner") that runs with at a low pressure, normally 200 mmH_2O (Fig. 1). Currently, LPG cooking burner ("Shower Burner") is used to be converted by NG burner without any rigorous criterion by installation technicians.

Beyond the security aspect of those cooks burners usage, another important aspect one must take in evidence is the energy efficiency program that normally is applied to the commercial stoves (ANP 2007). The

This paper presents the experimental methods and results of a R&D project aiming at an experimental study of LPG and NG burners' performance considering the thermal power, gas consumption, and efficiency as a way to establish a technically correct method of burner conversion according to the Brazilian standardization standards. This article presents the experimental study and a conversion method obtained that keeps the thermal equivalence between the two fuels for commercial stoves of "Chinese cooking "style.

Experiments were divided in three main parts: GLP burner tests, NG burner tests, and establishment of the conversion methods. In the first part a LPG burner was mounted and tested according to the condition as they are used in the regular Asian food restaurants. It means that those burners are plugged directly at the gas reservoir without any pressure regulator or any other safety device, representing a highly hazardous potential. The second part consisted of carrying out NG burner tests. A "Duck Bill" or NG burner was mounted and tested according to the above cited standards. In the same way fuel consumption, thermal power, and efficiency were obtained.

The third part consisted in proposing a conversion method based on a technically established criterion that permits installation technicians to perform correct conversion of LPG burners into NG burners keeping the same desirable heating power and cooking velocity.

2. METHODS

The experimental study was carried out following the ABNT NBR 13723-1:2003 and NBR 13723-2:1999 standards, from which recommendations were, followed on tests procedure, local conditions, and parameters formulations. Tests were divided in two different parts: the first part in which LPG cooking burners was tested, according to the real condition as they are used in Asian food restaurants; and the second part in which NG cooking burners was tested, according to the NBR 13723-1/2: 2003/1999 standards. Results obtained in the two tests were compared as a way to determine the thermal power equivalence between the two kinds of cooking burners.

2.1 Experiments

Experiments were carried out according to the ABNT NBR 13723-1:2003 and NBR 13723-2:1999 standards including ambient conditions, gas flow, and essay water recipients regulation. Some of the ABNT standards indicated are:

- Local ambient temperature must be between 293 and 298 K;
- Ambient temperature measurement must be made by a thermocouple located at 0.9 m above ground, 1.0 m to 1.5 m far away from the stove, and be protected by radiations from stove;
- Thermal power and burner's efficiencies must be made heating an amount of water filled aluminum recipients whose dimensions varies according to the burner's power;
- Water temperature must be made by a thermocouple located in the central point of water mass into the recipients with precision of ± 0.1 K. Water mass must be heated from 293 to 363 ± 1 K;

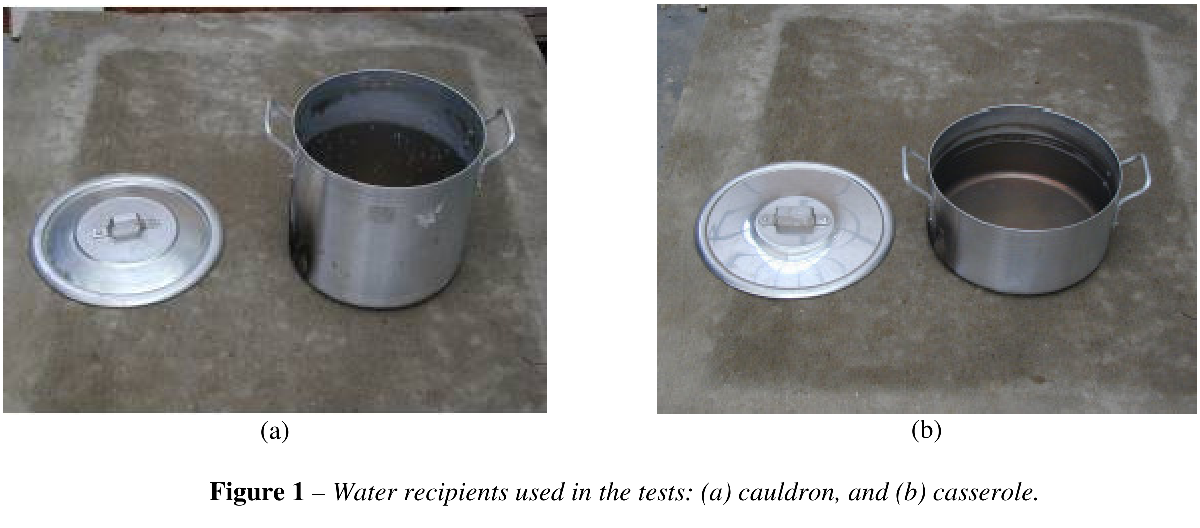
Some ABNT standard indications do not correspond to the burner's thermal power used in this test, so the EN 203-2-1:2006 was used to determine the water amount and the recipient's dimensions in accordance to the thermal power verified. LPG burners tests do not attended completely to the standards had been carried out according to the regular usage conditions.

The water recipients were made by aluminum and dimensions are described in Table 1. Figure 2 shows the water recipients used in the tests.

Table 1 – *Water recipient dimensions.*

Recipient	Total Volume (m^3)	Water Volume (m^3)	Water Mass* (kg)	H/D
Cauldron	0.0125	0.0094	9.34	0.923
Casserole	0.0080	0.0060	5.97	0.482

*@ 293 K



(a) (b)

Figure 1 – *Water recipients used in the tests: (a) cauldron, and (b) casserole.*

The gases used during the tests were LPG (Liquefied Petroleum Gas) and NG (Natural Gas), and its properties are described in Table 2.

Table2 – *Physical properties of used gases.*

Gas	PCI (kcal/m^3)	PCS (Kcal/m^3)	Density (kg/m^3)	Relative Density (-)
LPG[1]	26,000.00	24,000.00	2.00	1.80
NG[2]	8,591.49	9,507.53	0.76	0.63

[1] source: ANP; [2] source: COMGAS

2.1.1 Cooking burners tests

The first tests were carried out with the LPG cooking burner according to the real condition usage in the restaurants. Those conditions were initially verified *in loco* by visiting some Asian food restaurants as a way to obtain the most information quantity as possible to recreate it at the laboratory tests. The LPG cooking burner is commonly called by "Shower Burner" because your burner nozzle's appearance as can be seen in Fig. 2(a). They are formed by a injection nozzle with orifice diameter D_{LPG} = 0.7 mm, a simple ball valve at the gas inlet to the gas flow control, and an air/gas mixing chamber that conduces the mixture to the burner nozzles in which combustion occurs.

The second tests were carried out with the NG cooking burners following the ABNT and EN standards. As can be seen in Fig 2(b), the NG burners as compounded by a ball valve at inlet section to make the gas flow control, a gas chamber in which the nozzles are located. The NG cooking burner has a large number of com bustion nozzles with, each one, an injection nozzle with orifice diameter D_{NG} = 0.9 mm. This kind of cooking burner is commonly called "Duck Bill Burner", as can be seen in Fig 2(c)

(a) (b) (c)

Figure 2. *Burners pictures: (a) LPG ("Shower") burner, and (b) NG ("Duck Bill") burner.*

The LPG flow was measured with a balance with precision of 0.001 kg. A heat exchange was inserted to guarantee that the gas temperature was always according to the standards, and a pressure regulation valve permitted to establish the gas pressure at the burner's inlet nozzle as can be seen in Fig 3(a). The maximum pressure measured into the LPG tank was about 600 kPa, but the maximum pressure tested was 500 kPa as a way to guarantee a long as possible test time keeping the same pressure. The minimum pressure tested was 300 kPa because at that pressure the gas composition is not homogeneous and physical properties changes.

The NG test arrangement consisted by NG tanks with liquefied gas, a gasification and a pressure regulation system to furnish NG at 1.96 or 2.45 kPa. Those are the regular NG pressures in the residential and commercial gas lines. Flow measurements with precision of 0.001 m^3 was used to the NG flow measurement.

The tests consisted, basically, in measure the gas flow during the time needed to increase the water mass temperature from 293 to 363 K, for each cooking burner, and calculate their thermal power as indicated by ABNT NBR 13723-1:2003.

The standard establishes that the thermal power is given by Equations (1) and (2), as follows:

$$P_n = 0.278\, M_n\, PCS\ (or\ PCI) \tag{1}$$

or

$$P_n = 0.263\, V_n\, PCS\ (or\ PCI) \tag{2}$$

where,

P_n is the nominal thermal power [kW];
M_n is the gas nominal mass flow rate obtained at reference conditions [kg/h];
V_n is the gas nominal volumetric flow rate obtained at reference conditions [m^3/h];
Obs: The reference conditions are ambient pressure of 103.1 kPa and ambient temperature of 288 K.
PCS and *PCI* are the gas gross calorific value and lower calorific value, respectively. Several details can be seen in ABNT standards.

According to the ABNT NBR 13723-2: 1999, the burner's thermal efficiency can be calculated by Equation (3) as follows:

$$\eta = \frac{[M\ Cp\ (T_2 - T_1)\ 100]}{(V_C\ PCS\ or\ PCI)} \qquad (3)$$

where,

η is the cooking burner thermal efficiency [%];
M is the equivalent mass (water + recipient), $M = M_1 + 0.213\ m$ [kg];
M_1 is the water mass [kg];
m is the recipient mass [kg];
Cp is the water calorific value [4.186×10^{-3} MJ/kg.K];
T_1 is the water initial temperature [K];
T_2 is the water final temperature [K];
V_C is the gas volume used to heat water from T_1 to T_2 obtained at reference conditions [m3];
PCS and *PCI* are the gas gross calorific value and lower calorific value, respectively [MJ/Nm^3].

As it has been commented before the main objective of this work is to establish a conversion method that will guide NG burners installation professionals in converting existing LPG into NG cooking burners, keeping the same thermal power. The way is to determine the average unitary NG nozzle thermal power (P_{nN}) and, after that, to determine how much NG nozzle (N) are necessary furnish the same LPG cooking burner thermal power (P_{nLPG}). So, professional can construct a NG cooking burner that have the same thermal power than that installed LPG cooking burner.

The number of NG nozzles used in a NG cooking burner to furnish the same thermal power than a LPG cooking burner is given by Equation (4), as follows:

$$N = \frac{P_{nLPG}}{P_{nN}} \qquad (4)$$

where,

N is the number of the NG nozzles necessary to furnish the same thermal power than a LPG cooking burner;
P_{nLPG} is the LPG cooking burner thermal power used (depends on LPG used pressure) [kW];
P_{nN} is the average unitary NG nozzle thermal power determined experimentally [0.9 kW @ usage NG line pressure].

A conversion method can be established for LPG into NG cooking burners, according to standards and for the special operational conditions described before.

3. RESULTS

Tests were carried out with LPG and NG cooking burners for determining of both average thermal power under previous operational conditions. The LPG cooking burners was initially tested for determining of average gas flow rate and thermal power under 300 kPa to 500 kPa that represents that main usage condition by regular Asian food restaurants.

Tests for LPG flow rate shows that pressure influences strongly on the gas mass flow rate. For LPG pressure of 500 kPa the average mass flow rate is about 1.2 kg/h, for 400 kPa the mass flow rate is about 1.0 kg/h and for pressure about 300 kPa the mass flow rate is about 0.88 kg/h, as one can see in Fig. 3.

As the same way, the LPG cooking burner nominal thermal power is dependent on the mass flow rate and consequently dependant on the gas pressure as it can be seen in Fig 4. Results show that the average thermal power for gas pressure 500 kPa (1.25 kg/h) is about 15.4 kW and, as pressure falls the thermal power also falls for 10 kW for a pressure of 300 kPa (0.8 kg/h). It's important to note that for this kind of burner, there is only one injection nozzle responsible to the total LPG flow. According to the Equation (3), the average LPG cooking burner thermal efficiency is about 25%.

An 18 injection nozzles NG cooking burners was tested, and three different configurations (18, 14, and 10 injection nozzles) was performed and tested to verify the influence of an injection nozzles over the nozzle beside, or the influence of many injection nozzles on average unitary NG nozzle thermal power (P_{nN}). These kinds of burners have one injection nozzle in each burner nozzle, which is an important difference from the LPG cooking burner. The NG cooking burners mass flow rate was determined under a constant gas line pressure of 2.45 kPa, which is the standard NG line pressure established by the gas company. The NG mass flow rates was measured for the 18, 14, and 10 injection nozzles cooking burners, and results show 1.03 kg/h, 0.98 kg/h, and 0.8 kg/h, respectively. The average unitary NG injection nozzle mass flow rate for that pressure is about 0.07 kg/h, and the increase of the injection nozzles number decreses the unitary mass flow rate.

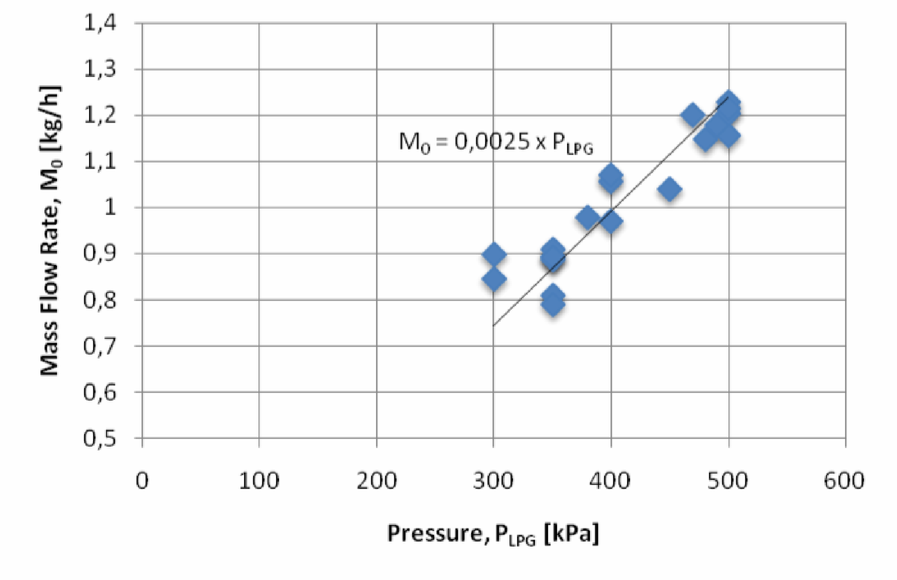


Figure 3. *The LPG flow rate as function of pressure.*

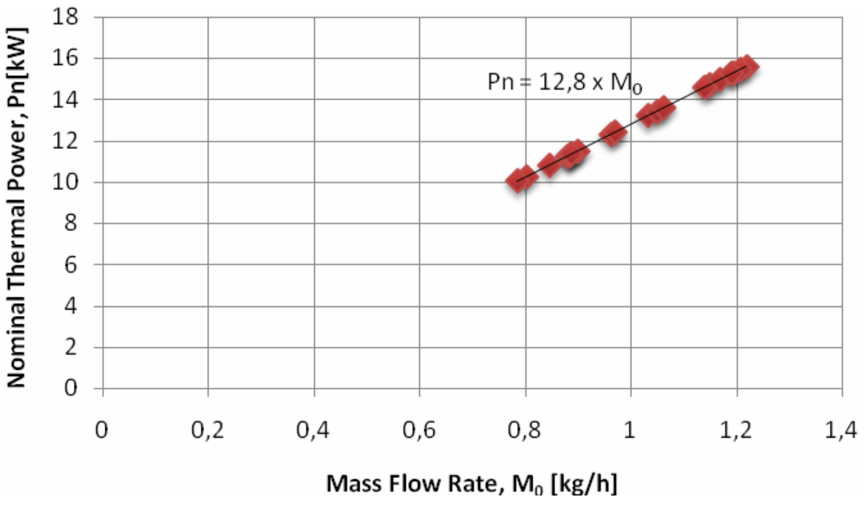


Figure 4. *The LPG cooking burner thermal power as a function of mass flow rate.*

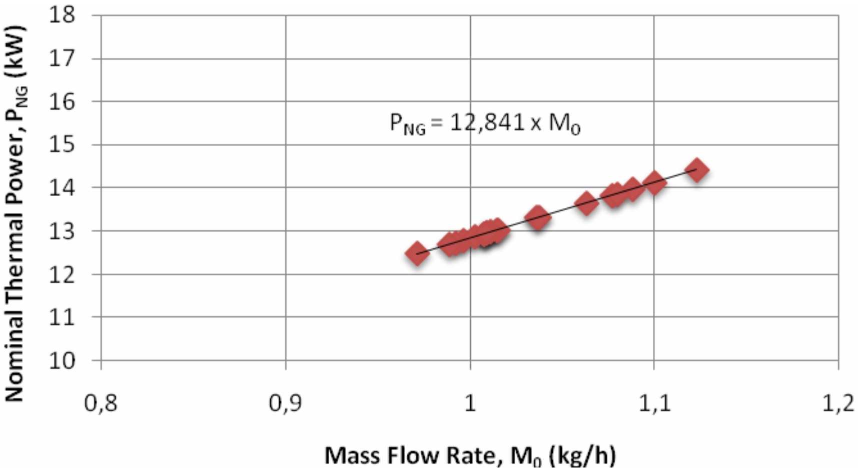


Figure 5. *The NG cooking burner thermal power as a function of mass flow rate.*

Figure 5 shows the linear relationship between the NG cooking burner thermal power and the mass flow rate. As one can expect, the average thermal power for the decays as a function of mass flow rate.

Table 3 shows the main experimental results obtained from the cooking burner`s tests.

Table 3. *Experimental results from burners.*

Burner		Average consumption per nozzle		Power (kW)	Power per nozzle (kW)	Efficiency (%)
		(Nm^3/h)	(kg/h)			
“Shower” (GLP)	5 bar	---	1.2	15.4	---	25
	4 bar	---	1.0	13.2	---	
	3 bar	---	0.88	11.2	---	
“Duck Bill” (GN)	18 nozzles	0.1	0.08	14.12	1.03	22.6
	14 nozzles	0.09	0.07	12.60	0.90	23
	10 nozzles	0.08	0.06	10.27	0.78	---

Obs: $P_{GN} = 200\ mmH_2O$.

4. CONCLUSIONS

Experimental methods and results of a study of LPG and NG burners’ thermal power and performances were carried as a way to establish a technically correct method of burner conversion according to the Brazilian standardization standards. The LPG (or “Shower” commercial stove) cooking burners was tested for determining average thermal power and efficiency under 300 kPa to 500 kPa that represents that main usage condition by regular Asian food restaurants. As the same way, the NG (or "Duck Bill" commercial stove) cooking burners were tested for both thermal power and efficiency determination.

Results permitted to establish a safety methodology for converting LPG cooking burnes into NG maintaining the desirable power for Asian food cooking as it was purposed initially.

This work contributes to a safe commercial stoves operation attending to Brazilian's standards and to the local NG distribution company standards.

5. ACKNOWLEDGEMENTS

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