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Technical-economic analysis of lpg level measurement in residential environment

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Marcelo Oliveira
Paulista State University - UNESP - Faculty of Engineering, Guaratinguetá - PRH 34.1

Andreas Nascimento
Federal University of Espírito Santo (UFES) - Brazil, Undergraduate Program in Chemistry

ABSTRACT
The health area seeks sustainable management models for making decisions with socio-environmental responsibility. This study uses a holistic methodology applied to understand the generation of solid health waste (RSS) between 2016 and 2022 in a large hospital in Goiânia-Goiás. Data available by the hospital administration were collected and RSS masses were collected. Procedures were applied for the reduction and segregation at the generating source. The exploratory approach with qualitative and quantitative aspects shows that the main residues are non-hazardous (Group D). Infectious, chemical and sharps wastes were distinguished. Training and environmental education activities were developed.

Keywords: Health care waste, Waste management, Source segregation.

1 INTRODUCTION

Liquefied petroleum gas (LPG) is widely used in cooking food by most Brazilian families, and is popularly known as "cooking gas". It has as characteristic to be one of the lightest fractions of oil and its burning is very clean, with very low emission of pollutants. Due to these characteristics, it is used indoors, such as in the kitchen, or in industrial applications sensitive to pollutants, such as in the manufacture of glass, ceramics and food (PETROBRÁS, 2021).

Currently, in the market, the level meters found for LPG cylinders have high cost, and those that have a good accuracy are focused on the industrial area. In addition, most of these meters are intrusive (need for a mechanical installation of gas pressure meter), or are inaccurate, such as those that check the level of LPG through the weight of the canister.

Considering the current price of the canister, this study is justified by the great use of LPG, in a residential way, not only in Brazil, but in many other countries. With the current price and the constant rise of the canister, it is in the world interest to discover a cheaper and more accurate form of level meters, which is not yet in the market.

The present work aims to demonstrate the various types of level measurement, in real time, of a lpg cylinder of home use, with low cost, which will allow the control of expenses and even better planning for the time of exchange.

As specific objectives, this study aims to analyze in detail the different forms of level measurement of a home-use canister, prioritizing low-cost forms. For such analysis, check the sensors, mechanical, electrical and electronic devices of low cost available in the market.

The problem of the present study, which should be covered and answered at the end of the research, will be through the following question: Is there in the market, an electronic system capable of measuring the amount of natural gas in a container of domestic use, with low cost and that is effective?

The methodology used for the development of this project will be bibliographic research, with a qualitative approach, through current technical-scientific articles that address the theme of gas level measurements (LPG) in a cylinder, of low cost.

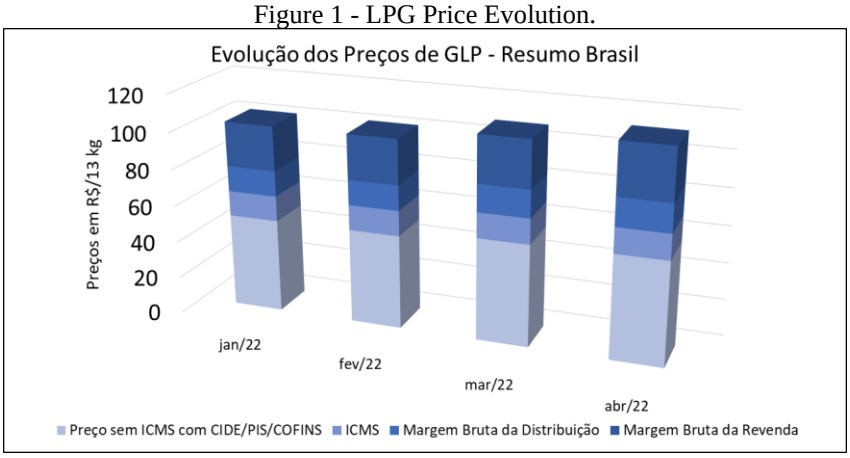
To understand the breadth of application of the idea presented in this project, as well as scope in terms of countries that could benefit, we will use articles from journals indexed on the Scopus platform and Web of Science, in addition to works registered on the OnePetro platform of the Society of Petroleum Engineers among other available articles.

In addition to the academically researched works with scientific references, it was also researched unusual methods of level measurement and not yet widely explored such as: measurement through warm water in the canister and temperature sensors that are magnetically coupled to the gas cylinder and can measure temperature.

1.1 LPG CYLINDER P-13 PRICE AND INFLUENCE ON BRAZILIAN FAMILIES

The ANP (National Petroleum Agency) publishes monthly the evolution of LPG prices in all Brazilian states since November 2001, and as shown in Figure 3 it is possible to verify that the prices of a canister currently cost around R$ 100.00 if it summarizes the price in all Brazilian regions. According to Provisional Measure No. 919, the minimum wage in Brazil is R$ 1,212.00, which means that a gas canister is equivalent to 8% of the salary of a Brazilian citizen. This type of comparison demonstrates the high cost of LPG and how its price mainly affects low-income families.

Figure 1 - LPG Price Evolution.



Source: ANP

The contents of a cylinder of 13 kg should be sufficient for the consumption of a family with four people in a period of one month. Therefore, 350 g, which is the allowed tolerance for a P-13 cylinder, corresponds to the consumption of approximately one day by this family. If we consider, for example, that a cylinder of P-13 costs, on average, R$ 100.00 in the city of Rio de Janeiro in April 2022, it can be concluded that 350 g of LPG (tolerance allowed for a P-13) correspond to approximately R$ 2.70 that can be paid by the consumer without receiving the product. According to ANP data, in a period of 6 months, about 200 million P-13 cylinders (containing up to 13 kg lPG) are sold. (Adapted from Nunes, 2017)

Effective and accurate control of the amount of LPG consumed in a family can bring economic benefits to a low-income family. Nowadays, there are different measuring devices that allow this type of control. In homes where gas is piped, meters are installed to measure the amount of gas consumed, but their high cost makes it impossible to install them in a house that uses cylinders.

In addition to the economic benefits that a control of the amount of gas can bring, this control also avoids the unexpected end of the gas in the cylinder during the cooking of a particular meal or procedure that depends on the combustion of the LPG. (Severus, 2018)

In this perspective, a survey conducted by students from the Federal Institute of Rio Grande do Norte found that about 75.8% of the interviewees, in a sample plan of 580 people, did not really know how long the gas would last until the next exchange. (Medeiros, 2017)

According to Barcelos [10], it is impossible to verify the remaining amount of gas in the cylinder, since there are no external indicators of the LPG level (the cylinder is completely sealed), which makes it impossible to see the liquid level.

2 METHODOLOGY

The methodology to be used for the development of this project will be through bibliographic research, with a qualitative approach, in which the data work in the search for its real meaning. As

conceptualized by Lakatos and Marconi (2001, p. 183) "it is one that covers all bibliography already made public in relation to the theme studied, from single publications, newsletters, newspapers, magazines, books, research, monographs, theses, cartographic materials, etc.", and its purpose is "to put the researcher in direct contact with everything that has been written, said or filmed on a given subject".

This research aims to search for market equipment and ways, alternative to conventional, of gas level measurements in a low cost canister, available in LPG distributors, for domestic use.

In addition to the studies researched academically and with scientific references, we also researched unusual methods of level measurement and not yet widely explored as: measurement through warm water in the canister and temperature sensors that are coupled to the gas cylinder and can measure temperature.

With regard to the objectives, this research can be classified as exploratory. According to Gil (1999), exploratory studies have as main objective to develop, clarify and modify concepts and ideas, with a view to the formulation of more accurate problems or researchable hypotheses for further studies. According to the author's words, the type of exploratory research is the one with the lowest degree of planning, because its scope is to provide an overview, of approximate type and its comparison with other methods.

Initially, current technical-scientific articles will be used to understand the breadth of application of the idea presented in this project, as well as scope in terms of countries that could benefit. To this end, articles from indexed journals on the Scopus and Web of Science platform will be used, in addition to works registered on the OnePetro platform of the Society of Petroleum Engineers.

After data collection of the chosen articles, a filtering will be made with the theme of said study, where the most relevant data will be extracted dand each publication as: year of publication, article title, authors, abstract, event, tools and techniques of data analysis, allowing to organize the objectives and themes addressed

Finally, the results and discussion of the research will be presented. Through the analysis of the results it will be possible to draw some conclusions from the published articles, contributing to future studies and recommendations.

3 RESULTS AND DISCUSSIONS

Different ways of measuring the level of a home-use canister were researched, prioritizing low-cost forms. Using conventional research methods such as the internet and scientific articles it was possible to verify 5 level measurement methods for a lPG cylinder for domestic use: measurement through the weighing of the gas cylinder, measurement through the internal pressure of the cylinder, measurement using ultrasonic technology, measurement through vibration signals and measurement through the temperature difference of the external temperature of the cylinder.

Thirty papers were pre-selected for the content of the title. After reading the abstracts, a selection of 20 articles was made, of which 10 were excluded because they did not meet the inclusion criteria, escape to the theme and articles with more than 10 years of publication.

Thus, 10 studies were included for the critical assessment stage. Table 3 presents the data extracted from each article differently.

Table 1 - Summary of the information contained in the articles surveyed

List of Published Articles on LPG Cylinder Measurement			
Year of publication	**Authors**	**Title**	**Methodology**
2015	Adam, A.A.	Ultrasonic instrumentation system to detect the level of liquefied petroleum gas in 14-kilogram cylinders	Ultrasonic measurement
2016	Juvana I.; Meenakshi, N.	Gas Level Detection and Leak Monitoring System using a Specific Technique	Pressure measurement
2017	Nunes, R.P.	Liquefied Petroleum Gas (LPG) as a Pre-Measured Product - A Study of Packaging Technologies and Measurement Control used by The National Industry	Vase technologies
2017	Zakaria et al.	Ultrasonic instrumentation system for liquefied petroleum gas level	Ultrasonic measurement
2018	Chagas, M.R.	Management of the level of cooking gas (LPG)	Pressure measurement
2018	Abid, M.	Monitoring gas cylinder level and gas infiltration detection via IOT	Measurement through mass
2019	Krishna et al.	Gas level measurement (LPG) using Arduino	Measurement through mass
2021	Barcelos et. Al.	Software registry (instrument + software): gasfeasible 1	Measurement through mass
2021	Vinnarasi, et al.	LPG gas monitoring system using Arduino	Measurement through mass
2022	Song et. Al.	Portable and non-intrusive fill state detection for liquid freight containers based on vibration signals	Measurement through vibration signals

Source: prepared by the author (2022).

3.1 LEVEL MEASUREMENT VIA ULTRASOUND

Of the ten articles surveyed, two of them, comprising Adam (2015) and Zakaria et al. (2017), had as methodology - to monitor the level of LPG in the cylinder - of measuring through ultrasound, emitting ultrasonic signals, which propagate through the cylinder wall.

A noninvasive procedure is required to perform level measurement in pressure vessels, corrosive liquids or closed vessels. Due to the enclosing of cylinders and vessels, ultrasound is usually suitable to be used for the noninvasive process. (Zakaria et al., 2017)

Zakaria et al. (2017) implemented an instrumentation system to monitor the Level of LPG in a cylinder of 14 kilos, which is similar to the 13 kg we found in Brazil. The instrumentation system has been integrated with an experimental platform and Truma ultrasonic sensors. LC-V1.15 was mounted vertically off the cylinder wall on an experimental platform sensor holder. The sensors emit the ultrasonic signals and the signals propagate through the cylinder wall. An image showed the level of liquid in percentage value. The instrumentation system developed was able to detect the LPG level in the cylinder with a 10% error.

Regarding the results found, in Adam's study (2015), the instrumentation system developed was tested in a 14 kg and 18L LPG cylinder, and the ability to detect the amount of LPG contained in each cylinder was verified, with a margin of error of a maximum of 5.68%. Also in the studies by Zakaria et al. (2017), it was possible to detect the level of LPG in the cylinder through the ultrasound system.

Ultrasound measurement is a method that has proved non-intrusive and efficient, but the cost of the sensor makes it impossible to use it by low-income families. The complete level measurement solution presented by truma company costs around R$ 600.00. The solution consists of a sensor that is coupled to the top of the LPG cylinder and communicates via Bluetooth with any mobile phone as shown

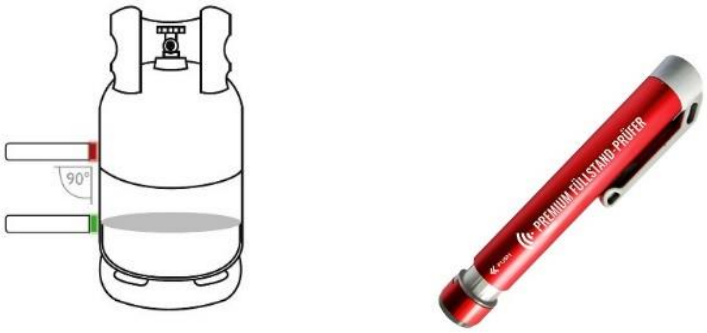
Figure 2.

Figure 2 - Example of a level meter with ultrasonic technology

Source: Truma.

There are also products on the market that use ultrasound technology, in equipment in the form of a stick, which are portable and easy to handle, such as the product presented by Obelink, which costs around R$ 200.00. For low-income families, this equipment continues to have a high cost.

Figure 3 - Example of a level meter with ultrasonic technology.



Source: Obelink.

3.2 LEVEL MEASUREMENT THROUGH CYLINDER PRESSURE

The studies by Juvanna and Meenakshi (2016) and Chagas (2018) used as a measurement of the gas level, through pressure. In this measurement system, the sensor measuring signal is sent to the controller, where the signal corresponding to the LPG level is processed, and a limit value is set, which after reached, sounds an alarm to the user.

Both studies by Juvanna and Meenakshi (2016) and Chagas (2018) were able to monitor, through pressure measurement, the gas level of a canister (LPG), promoting the prediction of the exchange. That way, a database search will occur through an Android app, with real-time status, anywhere in the world.

Both works referenced in this work present digital sensors for the measurement of cylinder pressure, but it was found that it is very common to use mechanical sensors with current cylinder pressure dials as shown in Figure 5. These meters are also known as gauges.

Figure 4 - Example of cylinder pressure gauge.

Source: Reference Center for Physics Teaching.

Inside the cylinders the gas is kept in a liquid state under pressure, between 4kgf/cm² to 7kgf/cm² (Petrobrás, 2021). At 20º C the liquid and gaseous phases (steam) of propane coexist in equilibrium if the pressure is about 7 atm, that is, if the pressure is equal to the saturated vapor pressure (Silveira, 2014).

According to Silveira (2014), the internal pressure on the canisters is the same, no matter the capacity. That is, in a cylinder, regardless of its capacity, and regardless of the amount of liquid and steam

present in the cylinder (provided that the composition of the mixture of different substances such as propane and butane is the same), the equilibrium pressure is completely a function of temperature, a function known as the Clausius-Clapeyron law.

Thus, a large cylinder and a small cylinder, at the same temperature, containing the same mixture (same substance with the same composition), will assume the same pressure if the two phases are in equilibrium inside. When the amount of "gas" in the cylinder decreases, if the temperature remains the same, the pressure will remain the same, the composition has not changed and there will still be liquid remaining. (Silveira, 2014)

Knowing that the pressure inside the cylinder will be the same, even with the variation in the amount of LPG in liquid state, we can conclude that the pressure meter will not inform the correct level of LPG inside the cylinder, but the meter will be able to indicate the moment of change of the cylinder, because when the amount of LPG contained in the cylinder is low, the pressure inside the cylinder reduces.

Measuring cylinder pressure is a method of checking the gas level in a cylinder, but this type of measurement is intrusive (need for a mechanical installation of a gas pressure meter) and the installation can be dangerous. As mentioned earlier, the full LPG cylinder has about 15% steam and 85% in its solid state and this proportion changes as LPG is consumed. Because the sensor measured the pressure inside the cylinder, it is often not measuring the amount of liquefied LPG properly. This method is inaccurate because the temperature inside the cylinder and the physical properties of LPG are able to modify the pressure, and this can cause an inaccurate measurement of the gas level.

3.3 LEVEL MEASUREMENT THROUGH CYLINDER MASS

Mass measurement was the most used among the ten studies, totaling 4 studies: Vinnarasi et al. (2021), Barcelos et al. (2021), Abid (2018) and Krishna (2019), and Vinnarasi et al. (2021) and Abid (2018), opted for a gas system using IoT, using a continuous measurement of the weight of the canister, with the interface of an Arduino Uno, as a value comparison and, able to inform the user of the time of the canister exchange.

In the mass measurement of the study by Krishna et al. (2019), a security-oriented system was also designed, with alerts via mobile phone for the user. The system detects the leak and sends a message to the user, automatically shutting down the LPG supply.

According to Krishna et al. (2019), the system studied can help users find out whether or not they are being deceived by some gas supply agency, as well as older people.

The study by Barcelos et al. (2021) created a concept with the name gasfeasible 1.0, where it presented an innovative proposal, which allows remote access to gas measurements remaining in the cylinder.

Regarding market projections and commercial acceptability, it was found, in the study by Barcelos et al. (2021), that the project developed for measurement through mass, using GasFeasible 1.0, with update to version 2.0, it is expected great potential for acceptance by Brazilian users. Its low cost, around R$ 112.00 in 2021, showed good potential for use by low-income families.

Both in the studies by Abid (2018) and Vinnarasi (2021), the results of the proposed systems about those in the market were satisfactory, as it offers an agile response to events such as gas leaks.

Measurement through cylinder mass is a method that has proved non-intrusive and efficient. Being the most used by industries and also in research projects in academia. The cost of a load cell or a complete equipment as a scale for example can have low costs and this enables the use of this technology by low-income families.

The disadvantage of this method is the fact that it is always necessary to know the weight of the empty cylinder, that is, it is necessary to check the mass of the gas cylinder before starting the filling of it.

3.5 MEASURING VIA VIBRATION SIGNALS

Song et al. (2022) presented a non-intrusive system, in which the liquid level is determined in responses to an external movement, using an accelerometer and solenoid, affixed to the outside of the cylinder, generating a pulsed excitation. In this case, the contents of the container can be detected.

The results for the study by Song et al. (2022) showed that the fixation of the actuator and sensor at the base of the container was the best in the aspect of detection and accuracy. The accuracy was 100% for binary classification and for quantized level exceeded 80%.

The study by Song et al. (2022) was done focused on railway containers and tank wagons used for the transport and storage of liquids, but this method could also be used for the domestic cylinder. The system is similar to the ultrasonic method, but the vibrations analyzed have a lower frequency that does not go more than 2000 Hz, according to the study presented.

In the work of Song et al. (2022) equipment was used that has a high cost for low-income families, such as the accelerometer, but we can identify for future work the possibility of accelerometers with a lower cost.

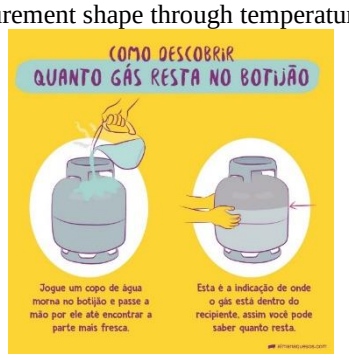
3.6 MEASUREMENT THROUGH CYLINDER TEMPERATURE DIFFERENCE

In addition to the researched works from academic sources and with scientific references, we were also researched in formal methods of level measurement and not yet much explored.

A way widely used by families is to throw hot water into the gas canister, as the LPG has a liquid part and a gaseous part inside the cylinder, the liquid part will absorb the heat from the water more quickly

than the gaseous part, so the part of the cylinder that is colder will indicate where the LPG level is as Figure 6 indicates.

Figure 5 - Example of measurement shape through temperature difference in the cylinder.

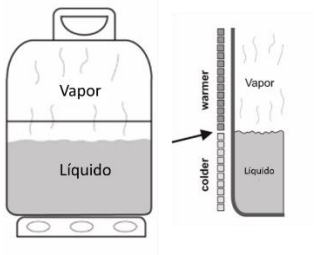


Source: Almanac SOS

According to Chagas (2018), to move from the liquid state to the state of steam the gas needs to 'gain heat' from the environment. Therefore, when the LPG is being consumed from the canister, the liquid cools, which in turn cools the cylinder within a few moments. There are on the market, meters capable of detecting this temperature change on the outside of the cylinder.

Usually this type of meter, has different columns, because these columns allow the meter to work with the variation of the ambient temperature. These columns are composed of thermochromic liquid crystals, which are able to change color according to temperature (LCRHallcrest, 2022).

Figure 66 Example of level measurement through temperature difference.



Source: LCRHallcrest

For the operation of this type of meter, it is necessary that the LPG is being consumed so that there is a temperature difference in the cylinder. The columns, or bars of the level indicator, will have their colors changed, and where this change is detected the LPG level will be indicated inside the canister. (LCRHallcrest, 2022).

The measurement of LPG level through the cylinder temperature difference is a method that has proved non-intrusive and low cost, because each sensor costs around R$ 15.00. However, this type of sensor has some limitations, because it works only when the LPG is being consumed and still in the lPG cylinder welding it is not possible to install the meter, which causes an area of the cylinder to go unmetered.

4 CONCLUSION

Bottled liquefied petroleum gas (LPG) is one of the important living materials, and its net content has been one of the issues that requires a lot of care, which also makes it one of the main points of supervision by the competent departments.

On the one hand, because they are flammable and explosive products, it must first meet safety requirements and then meet measurement requirements.

Neither insufficient filling can harm consumers nor excessive filling can cause safety risks. In this context, the types of measurement of gas levels in kitchen cylinders available in the market and their functionalities were investigated through this study.

Users are unable to view the level of the LPG cylinder used daily, and the sudden exhaustion of this cylinder can cause discomfort to the user, which will result in frustration, as the delivery of a new LPG cylinder takes time. The LPG is coupled to the burner through a regulator that can interrupt the supply of LPG to the burner. In addition, fire accidents are unpredictable when there is lPG canister leakage that can cause serious damage to people and property.

In view of this study, it was concluded that, among the various measurement systems researched, some more affordable at the cost level were identified, and others less, taking into account the profile of many Brazilians who use the kitchen canister at home.

The pressure system was one of the most relevant under study, because this type of system, with development of the pressure detection scheme, gives information about the pressure change of the container, presents the level of gas inside the cylinder and warns the user. This continuous measurement is done using a pressure sensor installed on the cylinder. The updated value is displayed and the alarm is activated when the threshold is reached. The gas leak, if any, is detected by the specific sensor and alerts the user.

Thus, the problem of the study is answered, proving that there are several monitoring systems of cooking gas level, capable of measuring the amount of LPG in a cylinder of domestic use, with low cost and that is effective.

Among the lPG cylinder level monitoring systems, we can conclude that the method with the lowest cost and that it has efficiency is that by checking the weight of the cylinder. This method has been used by industry for LPG nursing and has also been studied by several educational institutions.

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