ULTRASONIC INSTRUMENTATION SYSTEM FOR DETECTING LIQUEFIED PETROLEUM GAS LEVEL IN 14 KILOGRAM CYLINDERS

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Dedicated to my beloved parent, ummi and abah,

and all my lovely siblings,

thanks for your love and encouragement

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ABSTRACT

Liquefied Petroleum Gas (LPG) is commonly stored in highly pressurized cylinder tank and needs to be measured using a non-invasive way. This approach has been constructed to facilitate the process of LPG level measurement inside a cylinder tank. Currently, liquid level of LPG inside a cylinder is measured using a weighing scale. In this research, a new method is developed by using a non-invasive ultrasonic instrumentation system for monitoring LPG level in the 14 kilogram cylinder. The instrumentation system was integrated with the designed experimental rig. Module ultrasonic sensors Truma.LC-V1.15 were attached vertically outside of the cylinder wall on the sensor holder of the experimental rig. The ultrasonic sensors emit the ultrasonic signals and the signals will then propagate through the cylinder wall. The reflected signal was recorded again by the ultrasonic sensors. The reflection of the ultrasonic signal depends on the type of the medium's impedance. The generated signals from the transceiver type of sensors were sent to the Pico Scope Data Acquisition System (DAQ) for data reading. The output voltage signals were processed by the computational data process system, giving a result of the LPG liquid level inside the cylinder. An image of the LPG liquid level in the cylinder was constructed using javascript based programming. The image showed the liquid level in percentage value and html software was used as the interface in this program. The developed instrumentation system was also tested on 18-L testing cylinder and 14-kg LPG cylinder with various LPG liquid levels and it was able to detect the amount of LPG in the cylinders, with the maximum error of 5.68%.

ABSTRAK

Petroleum Gas Cecair (LPG) biasanya disimpan di dalam silinder bertekanan tinggi dan perlu diukur dengan cara tanpa musnah. Cara ini telah dibina untuk memudahkan proses pengukuran aras LPG di dalam tangki silinder. Pada masa kini, aras cecair LPG di dalam silinder diukur menggunakan alat penimbang berat. Dalam kajian ini, satu kaedah baru dibangunkan menggunakan sistem peralatan ultrasonik tanpa musnah untuk memantau aras LPG di dalam silinder simpanan berkapasiti 14 kilogram. Sistem peralatan ini disepadukan dengan rekaan pelantar eksperimen. Modul deria ultrasonik Truma.LC-V1.15 telah dipasang pada pemegang sensor pelantar eksperimen. Deria ultrasonik tersebut dipasangkan secara menegak di luar dinding silinder. Deria ultrasonik memancarkan isyarat ultrasonik dan isyarat telah tersebar menembusi dinding silinder. Isyarat pantulan dirakam semula oleh deria ultrasonik. Pantulan isyarat ultrasonik bergantung kepada jenis galangan bahan perantara. Isyarat yang dihasilkan dari deria jenis penghantar-terima telah dihantar ke Pico Scope Data Sistem Perolehan (DAQ) untuk membaca data. Isyarat voltan keluaran diproses oleh sistem proses data perkomputeran untuk memberikan aras kandungan cecair LPG di dalam silinder. Pembinaan imej aras LPG dalam silinder dibina menggunakan pengaturcaraan berasaskan javascript. Imej tersebut menunjukkan imej aras LPG di dalam nilai peratusan dan perisian html digunakan sebagai perantara muka pada program ini. Sistem peralatan yang dibangunkan diuji pada 18-L silinder ujian dan 14-kg LPG silinder yang berbeza aras cecair LPG dan sistem ini berjaya mengesan jumlah LPG dalam silinder dengan ralat maksimum 5.68%.

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LIST OF ABBREVIATIONS

ASTM	-	American Society for Testing and Materials
CFC	-	Chloro Fluoro Carbon
DAQ	-	Data Acquisition System
DC	-	Direct Current
GMB	-	Gas Malaysia Berhad
HHV	-	Higher Heating Value
HTML	-	Hyper Text Markup Language
LHV	-	Lower Heating Value
LPG	-	Liquefied Petroleum Gas
MSDS	-	Material Safety Data Sheet
NDT	-	Non Destructive Testing
PC	-	Personal Computer
PZT	-	Lead Zirconium Titanate
PVC	-	Poly Vinyl Chloride
STP	-	Standard Temperature and Pressure
TOF	-	Time of Flight
UT	-	Ultrasonic Testing

LIST OF SYMBOLS

π	-	Pi, 3.14
ρ	-	Density
a	-	Depth of Head or Bottom
θ	-	Angle
atm	-	Atmospheric Pressure
avg	-	Average
c	-	Speed of Light
cm	-	Centimeter
D	-	Diameter
g	-	Gram
h	-	Height of Liquid Level
kg	-	Kilogram
J	-	Joule
kHz	-	Kilohertz
L	-	Length
m	-	Meter
mm	-	Millimeter
MHz	-	Megahertz
MJ	-	Megajoule
r	-	Radius
R	-	Reflection Coefficient
Rayl	-	Rayleigh
S	-	Sensor Number
t	-	Time
T	-	Transmission Coefficient

V	-	Voltage
υ	-	Volume
W	-	Weight
Z	-	Acoustic Impedence
°	-	Degree
°C	-	Degree Celcius
°F	-	Degree Fahrenheit
E	-	Wave Energy
S	-	Sensor
T	-	Transmitter
C_3H_8	-	Propane
C_4H_{10}	-	Butane
% e	-	Percentage of Error

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CHAPTER 1

INTRODUCTION

1.1 Project Background

Oil and gas are natural resources that contribute as the source of fuel to most of the countries in the world for its economic expansion. Many nations depend on these natural resources for growth and development of their countries. It is necessary to ensure that the natural resources can be transported safely from its original plant or storage to the consumers throughout the countries (Bannon, 2003).

The transmission process and storage technique of oil and gas must be in control because of its natural characteristic that is highly volatile and flammable. There are many methods used to transfer these oil and gas supply to the market such as tanker, pipeline barge, rail and truck.

Liquefied petroleum gas (abbreviated as LPG) is a chemical compound that usually used as a fuel for cooking, combusting and burning tool and also used for transportation energy source. This inflammable mixture is widely used as an aerosol propellant and a refrigerant. The LPG replaced CFC in an effort to reduce the effect of green house and protect the ozone layer (Bejan, 1999).

There are various types of LPG mixture available in the market and the mixture of their composition are different for each country and depend on the seasonal weather of the country. There will be more propane in winter while more butane in summer (Totten, 2003). There are types of mixes which are mainly propane (C_3H_8), and mainly butane (C_4H_{10}). The mostly common mixes were the mixture of both propane and butane in a certain percentage.

Substance of propylene and butylenes are normally present but in a little concentration. LPG is basically in gas or liquid phase which is odourless and colourless. Therefore, it is difficult to detect whether there are any existence of LPG or not. The odorant like ethanethiol, is incorporated with LPG so that leaks can be recognize easily. In the United States, thiophene known also as amyl mercaptan is an approved odorants (Mahalingam, 2012). Figure 1.1 shows the example of LPG cylinders commonly used today.

Figure 1.1 Cylinders with LPG

LPG will be vaporise when exist in room temperatures and pressures. LPG is pressurized in a special designed cylinder that is capable of storing large pressure content. The cylinder also designed appropriately in order to fulfil the supply and demand on market daily use. Typically percentage of filling is between 80% to 85% of their storage capacity. This would allow the thermal expansion of the LPG (Zakaria *et al*, 2006).

Unlike natural gas, LPG is heavier than air, thus will flow along floors and tend to settle in lower spots, such as basements. (Soundarya *et al*, 2014). Large amounts of LPG usually stored in a bulk cylinders typically aboveground, underground or mounded. Periodic inspection and testing of the storage must be done to ensure safety standards are maintained.

1.2 Problem Statement

Liquefied Petroleum Gas (LPG) becomes the most popular source for household and commercial uses. Basically, when compared to other liquid fuels, LPG is flexible to handle and having lesser pollution with minimum space used for storage. LPG will be delivered to the customer either by using cylinder, bulk tank or pipeline. There are several ways of LPG distribution to customers depends on the type of customer i.e. whether it is domestic, commercial or industry. Figure 1.2 shows an example of manifold LPG system installation for commercial use.

Figure 1.2 Manifold LPG system (Primagas, 2009)

LPG consumption for every customers were different depending on the rate of use. There were consumers who used LPG daily at a high rate such as the laundries that uses for the purpose of drying clothes. Numbers of users only use a small amount of LPG for home cooking. The different on LPG consumption rate of consumers carries variation of usage among consumer thus requiring friendly LPG cylinder measurement. This idea was not as important for some consumers, but it was very significant for customers who utilized the LPG on a large scale basis especially for those who use it for commercial purposes.

Therefore, this research study is intended to develop an ultrasonic instrumentation system to measure the LPG residual in the cylinder in a better way using ultrasonic sensors. This study focused on the ability of the developed system in monitoring the presence of LPG and its level. This is the initial study to detect the LPG level imposed on the household LPG cylinders of a 14 kg capacity.

Most of LPG users, especially among commercial and industrial field were used weighing instrument in order to obtain the exact contents of LPG inside the cylinder. Some of them measured the amounts of LPG inside the cylinder by checking the content pressure. This method was often used by the refilling plant because this is the fastest way of measurement. This pressure type measurement was conducted in a rapid process because the filling process and the pressure readings were taken simultaneously. Figure 1.3 shows the example of weighing instrument for LPG cylinder. This machine was designed completed with the gas filler tool for LPG refilling process.

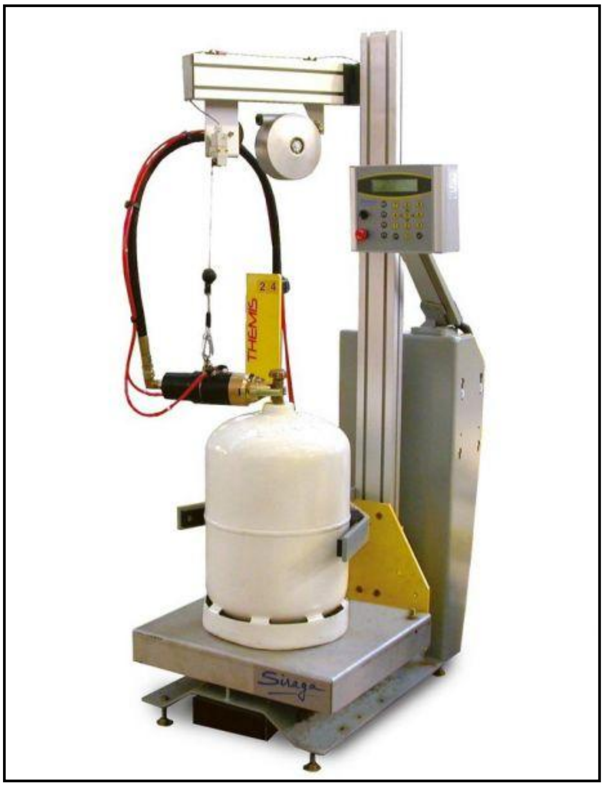

Figure 1.3 Weighing measurement of LPG cylinder (Siraga, 2008)

Ultrasonic instrumental technique was an acceptable way to monitor the LPG content in the LPG cylinder. This method is proposed because it can help the process of measurement in easy way using non-invasive procedure.

1.3 Objectives

The objectives of this project are:

i. To develop a non-invasive ultrasonic instrumentation system for detecting the LPG content in LPG cylinder storage.
ii. To monitor LPG residual inside the cylinder.

1.4 Scopes of Study

In order to achieve the objectives of this project, the scopes are:

i. Understanding the principal of ultrasonic measuring method on liquid level measurement.
ii. Development of instrumentation rig of LPG cylinder measurement.
iii. Performing the study on sensoring system optimization
iv. Setting up the ultrasonic instrumentation system including module sensor, Pico Scope DAQ, computational data process and image reconstruction.

v. Carry out preliminary experiment on testing cylinder 18L and LPG cylinder of 14 kg for instrumentation system calibration and accomplish the experimental measurement on four different types of LPG cylinder.

vi. Analyzing data receive from Pico Scope DAQ using computational data process system.

vii. Generating the percentage of LPG content information using html based programming.

1.5 Thesis Outline

Chapter 1 briefly presents the background information about oil and gas industry around the world. LPG is one of oil and gas product which is essential in our daily needs for household use, industry and transportation. LPG characteristics, transmission and storage system have been briefly defined. This chapter includes the problem statement, objectives and the scopes of the project. Chapter 2 explains the literature review about the measurement of LPG storage on recent industrial usage. The configuration systems of measurement and the suitable type of sensors are described in more detailed. Chapter 3 describes the methodology on LPG instrumentation system based on ultrasonic sensors to detect the LPG level. The outcome signals are explained to show the LPG level in suitable image. Chapter 4 presents results obtained from the experiments. Specific justifications and explanations about the output results are explained to validate and verify the correctness of the experiment. Chapter 5 combines the overall conclusions and some of recommendations for future improvements.

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