UNIVERSITY OF EDUCATION, WINNEBA

COLLEGE OF TECHNOLOGY EDUCATION, KUMASI
SCHOOL OF RESEARCH AND GRADUATE STUDIES

SAFETY AUDIT OF LOCALLY INSTALLED LIQUEFIED PETROLEUM GAS (LPG) TECHNOLOGY FOR LIGHT COMMERCIAL VEHICLES IN THE HO MUNICIPALITY OF GHANA

BY

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SEPTEMBER, 2013

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SEPTEMBER, 2013

DECLARATION

STUDENT'S DECLARATION

I, LAWRENCE KWAME MOTTEY declare that this Dissertation, with the exception of quotations and references contained in published works which have all been identified and duly acknowledged, is entirely my own original work, and it has not been submitted, either in part or whole, for another degree elsewhere.

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SUPERVISOR'S DECLARATION

I hereby declare that the preparation and presentation of this work was supervised in accordance with the guidelines on supervision of Dissertation as laid down by the University of Education, Winneba.

NAME OF SUPERVISOR: MR. STEPHEN K. AMOAKOHENE

SIGNATURE:…….

DATE:……..

DEDICATION

To my beloved daughters,

Cynthia Mottey and Elizabeth Mottey

for their supporting prayers*!!!*

ACKNOWLEDGEMENT

For preparing me for the task ahead with his Divine protection and guidance, I wish to acknowledge the Almighty God for seeing me through all my educational processes.

I also wish to express my warmest and profound gratitude to my lecturers of the College Of Technology Education, University Of Education, Winneba - Kumasi Campus for their support and assistance in my educational processes, and to the entire staff and management of vehicular safety organizations dealing with converted liquefied petroleum gas automobiles in the Ho Municipality and beyond for their roles in this educational research process.

To Mr. Stephen K. Amoakohene, my supervisor, I say, I am most grateful, for it was through your supervision and, a lot more, that has made this manuscript a reality.

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ABSTRACT

The principal aim of this project is to contribute its quota to development of converted automobiles to ultimately serve intended purposes, protect lives and properties absolutely against liquefied petroleum gas related accidents and to update knowledge and practice on Technology for accelerated development of the Ho Municipality, enhance policy analysis by Driver and Vehicle Licensing Authority and serve as a contribution to nation building. Random sample size of 212 converted automobiles representing 12.08% of the total 1,755 targeted population was deemed fit and utilized for generalization of analysis. Deplorable states and unavailability of some expected components and features, use of domestic cylinders and longitudinal mountings of fuel containers in boots, were some of the major findings. Virtually, no suffocation preventive means to protect health against fumes of fuel were made. Electrical wiring harness, connections and the use of fusible links to safeguard circuits had been seriously abused. It is imperative and cannot be over emphasized that concerted efforts be made to update converted liquefied petroleum gas automobiles in the Ho Municipality to meet Modern Developmental and International Safety Standards, so as to save lives and properties and give way to accelerated development of the city regardless of the cost factors.

CHAPTER ONE

INTRODUCTION

This chapter primarily justifies the essence of the research work. It basically comprises the background concept fo the study, statement of the problem, purpose of the study and the required research questions that facilitated the entire work. Significance of the study, Limitations and delimitations, definition of terms and the organization of the study inclusively and holistically give meaning to the rationale for the research work.

1.1. BACKGROUND TO THE STUDY

The conversion of a fuel supply system of an automobile to adopt and adapt the use of a particular fuel must be done with necessary precautions to ensure environmental safety and the welfare of occupants.

To avoid leakage of fuel, risk of fire, explosion and other environmental hazards associated with the use of automobiles and to ensure the ultimate safety, automobiles with any type and kind of fuel must be International safety regulatory requirements compliance, to be consistent with its usefulness.

Automobile is a self moving road vehicle, typically with four wheels, powered by an internal combustion engine to transport people, goods and services from one location to another through the conversion of the energy of fuel and air to heat energy, and from heat energy to mechanical energy that propels it.

It consists of basic mechanical parts and devices making up its systems. Each system fulfills a specific function or functions which when coordinated as a whole gives the automobile the realization of its objectives. These systems comprise the power unit known as the engine, the fuel supply system, transmission system, suspension system and steering system. Others include the electrical system, braking system, cooling and exhaust systems.

Automobiles generally use organic natured fuel to empower its internal combustion engines, but technological advancements have led to the design of cars that run on electricity and even water. Notable among organic natured fuels are gasoline, diesel, liquefied petroleum gas, compressed natural gas, ethanol and bio-diesel (Lee et al 2013).

Gasoline or petrol incidentally happens to be the most common fuel used in cars. It is presumably specialized fossil fuel designed for four-stroke engines like ones found in common cars. Gasoline has the merits of quick starting, fast acceleration, easy combustion and also quiet operation among others, based on the University of Michigan website (2013) publication on fossil fuels. Ironically, the hydrocarbons contained in gasoline and its production of carbon dioxide when burned contributes to pollution, smog and global warming. Globally and predominantly, it is the most readily available fuel, but considered to be a temporary source of fuel dependent on its cost, environmental effects and limited resources.

Diesel fuel is typically used in heavy duty transport vehicles such as tractor-trailer trucks, buses, boats and trains. Like gasoline, this fossil fuel is also non-renewable. Even though diesel contributes less carbon dioxide to the environment, it creates more organic compounds and

nitrous oxide that cause smog. According to the Petrol Prices website (2013), vehicles operating on diesel tend to last longer than gasoline vehicles, and have 30 percent better fuel efficiency than the average gasoline vehicle.

Liquefied Petroleum Gas (LPG), which is otherwise known as propane, is a clean fuel alternative to gasoline and is being used in common vehicles on a limited basis. Most hybrid cars in the United Kingdom have been designed to operate on propane, but generally the practice of getting a propane vehicle in the United States is to have a gasoline engine converted. Liquefied petroleum gas produces fewer toxins when burned and does not contribute to smog in the same way as diesel and gasoline. Propane's popular merit in even a layman's perspective is its less expensiveness as compared to gasoline.

Compressed Natural Gas Engines operating on gasoline and diesel can be converted to run on compressed natural gas. It is a clear, odorless and non-corrosive gas that has the potentials of being used in liquid or gas forms to run combustion engines. Vehicles designed with compressed natural gas fuel system are expected to produce 80 percent less ozone-forming emissions than gasoline burning cars, according to Consumer Energy Center website of California Energy Commission (2013).

Ethanol is frankly bio-fuel alternative to gasoline. Its production can be achieved by the conversion of sugar cane, corn, barley and other natural products. Ethanol's popularity as a fuel source can be traced down to the fact that it is one of the only fuels that can fuel a gasoline engine without any modification. Many car models have the possibility of running on 100

percent ethanol, but it is commonly used as an additive to help cut down on the emissions and contamination caused by pure gasoline components. E10, for instance is gasoline mixed with 10 percent ethanol, available at most gasoline stations right in America, and some places even use higher concentrations.

Bio-diesel is confirmed to be diesel substitute made from sugar beet, rapeseed or what is commonly known as palm oil. Certain individuals sometimes formulate this substance by collecting used oil from restaurant fryers. It is a fuel that burns much cleaner than standard gasoline or diesel and produces far less carbon dioxide emissions. However, continuous production of this fuel substance may result in unpardonable deforestation if stringent measures are not put in please to avert the situation.

The fuel supply system of an automobile is responsible for processing and delivery of expected charge of fuel and air mixture in its correct proportion for completeness of combustion in the engine for derivation of mechanical power and its likes for the use of the automobile.

The fuel must be finely atomized to mix with the air for the best results. It is therefore the purpose of any fuel supply system to deliver fuel to its engine in a form in which it can thoroughly mix up with the air to form a combustible mixture that enhances complete combustion. To this extent, various mechanical components and devices are designed and harnessed together to ensure this all important function, depending on the type of fuel in use.

Automobiles released from factories originally, are usually safety regulatory compliance and are from time to time examined to ascertain their roadworthiness when put to use. Automobiles to be converted to adopt and adapt the use of a particular fuel different from its originally made also need to be handled by experts and supervised to meet safety regulatory requirements standards. Equally, these converted vehicles need to be examined or audited to ensure their compliance to international safety regulatory requirements standards so as to ascertain their viability or roadworthiness, devoid of fuel related hazards and to safeguard lives and properties in their use.

1.2. STATEMENT OF THE PROBLEM

Government of Ghana imported automobiles which are originally gasoline or petrol driven to better or enhance lives for its citizens. Ironically, private transport operators and some individuals in the Ho Municipality of Ghana and some other parts of the country converted these vehicles locally to using liquefied petroleum gas (LPG) as source of power. Liquefied petroleum gas (LPG) like other organic natured fuels used by automobiles is highly flammable and has the tendency to pollute the air in a given environment and pose other health hazards to humanity if not well handled. This practice has led to suffocation of occupants of some of these vehicles and some vehicles getting ablaze at the slightest provocation at service.

Ho as a developing capital city of the Volta Region in Ghana needs to have the nature and conditions of its automobiles meet International Safety Standard. Vehicular population in the city is on the ascendancy and population growth of human is overwhelming. Predictably, these population explosions can lead to increase automobile related accidents or hazards in the city if reliable measures are not put in place to check its menaces.

Recent developments on automobile accidents that have occurred in the Ho Municipality ware blamed on the nature and conditions of the vehicles converted to run on liquefied petroleum gas (LPG). It is against this backdrop that Safety Audit of locally installed liquefied petroleum gas (LPG) technology for light commercial vehicles in the Ho Municipality of Ghana is seen as a measure in the right direction and recommended to be conducted towards the protection of lives and properties for national development. Safety audit of these automobiles can probe the certainty of the nature and conditions of the vehicles and pinpoint the areas that need to be addressed in order to mitigate vehicular fuel related accidents and health hazards, if not totally eradicated.

1.3. PURPOSE OF THE STUDY

It is the principal aim of this project to see Ho become well developed city with an excellent nature and conditions of its automobiles that can ultimately serve their intended purposes and protect lives and properties absolutely against automobile fuel, specifically liquefied petroleum gas related accidents and its health hazards, as the International Safety regulatory Standard demands.

In order to achieve this principal aim, the following objectives are substantiated:

(i) To identify accident prone areas of the fuel supply system of locally converted automobiles using liquefied petroleum gas in the Ho Municipality and how best they can be resolved to serve their intended purposes and to protect lives and properties on the streets of the Ho Municipality and its environs.

(ii) To verify whether or not safety devices are adequately provided to meet International Standard that should provide adequate and accurate services for the prevention of fuel related accidents and health hazards.

(iii) To ensure that adequate safety provision is made for occupants of these vehicles in the Ho Municipality without being harassed, endangered or destroyed by vehicular liquefied petroleum gas hazards.

(iv) To ensure that automobiles operating on liquefied petroleum gas in the Ho Municipality are of full benefit to the community and that can enhance accelerated development of the city and not a death trap for losing its potential citizenry.

1.4. RESEARCH QUESTIONS

In view of the statement of the problem, the following research questions are formulated to aid the research work:

1. How is the components necessary for the conversion of originally gasoline or petrol driven vehicle to liquefied petroleum gas (LPG) usage chosen?
2. How is the nature and conditions of the safety features or devices used on the liquefied petroleum gas (LPG) automobile?
3. How is the conversion done for effective operation that ensures safety?

1.5. SIGNIFICANCE OF THE STUDY

As the need or justification of the study, it is hoped that by the findings of this study and its recommendations, there will be firstly, update of knowledge and practice on Technology as to how the concept of gasoline automobile conversion to liquefied petroleum gas usage be done to meet International Safety Standard, to promote the optimum safety to saving lives and properties. Secondly, accelerated development of the Ho Municipality will be enhanced, since citizens and foreigners on business issues can go about their normal duties and responsibilities without wasting time, resources and energy for productivities on automobile related fuel hazards on LPG. Thirdly, the creation of room or the opportunity for policy analysis by the Driver and Vehicle Licensing Authority (DVLA) to adopt and adapt the findings and recommendations as benchmark upon which road worthiness examinations for LPG fuel automobiles can be based. Finally, this research work, on the part of the researcher, will serve as a contribution to nation building, since its outcome can influence the development of the entire nation and beyond.

1.6. LIMITATIONS OF THE STUDY

Safety audit of an automobile can be extended to cover a wider dimension, including all systems of the automobile to ensure its road worthiness, but this project is limited to only the fuel supply system that has to do with liquefied petroleum gas. Vehicle systems like wheels and tyres, the suspension, steering, braking and lighting systems are not covered by this research work.

Various fuel systems on automobiles also excite, depending on the type of organic natured fuel that is in use. Automobile fuel systems using gasoline, diesel, compressed natural gas, ethanol

and bio-diesel as fuel are not inclusive. The focus of the study is emphatically on automobile fuel systems using liquefied petroleum gas (LPG) as potential energy or fuel.

Ho is the capital city of the Volta Region of Ghana, and the headquarters of the Ho Municipality. However, this research work or studies does not cover the entire municipality. It is rather limited to the capital city alone which covers an area of about 20.570 square kilometers which is the heart of the city, with the belief that by so doing the entire municipality will have been taken care of since all vehicles eventually find their ways into the capital.

1.7. DELIMITATIONS OR SCOPE

As the topic of this project implies, thus, 'Safety Audit of locally installed liquefied petroleum gas (LPG) Technology for light commercial vehicles in the Ho Municipality of Ghana, the research is essentially covering how the components necessary for the conversion of originally gasoline or petrol driven vehicle to liquefied petroleum gas (LPG) usage chosen and their suitability for the varieties of LPG fuel supply systems available. Probing the nature and conditions of the safety features or devices used on the liquefied petroleum gas (LPG) automobiles for adequacy, functionality and precision in performance. Critical look at how the conversion is done in terms of locations, connectivity and relativities of features for effective operation that ensures safety.

1.8. DEFINITION OF TERMS

The following terms are commonly used in this project or presentation and need to be well defined:

Atomized fuel: Atomization of fuel is the breaking down of liquid fuel into the smallest particles that can thoroughly mix up with intake air to ensure complete combustion within the shortest possible period of time in the engine.

Automobile: The words 'Automobile' and 'Vehicle' are used alternatively in this handiwork to mean the same thing, thus road transport, usually with four wheels and powered by an internal combustion engine, designed to convey a small number of passengers, goods and services.

Backfiring : This is a fault in which combustion which is supposed to take place and be confined in the combustion chamber of an engine finds its way into the inlet manifold and beyond with damaging consequences.

Compliance: The conformity to standards, and in particular International Safety Standards.

Containment ducting: Tubular passage or special designed channel that directs potential leakages to the outside of the vehicle to prevent suffocation of occupants by fumes of liquefied petroleum gas.

Gasoline: Gasoline is commonly used to mean petrol as fusel fuel.

Retrofitting: Modifying a system of machinery or automobile by way of adding or installing newly developed parts or devices that were not available originally when the machinery or automobile was made, to serve or improve an intended purpose or purposes.

1.9. ORGANIZATION OF THE STUDY

This project essentially comprises six chapters. Chapter one deals with the background to the study, statement of the problem, purpose of the study and the research questions. Other aspects of the chapter include the significance of the study, limitations and delimitations of the study. Also in Chapter One are the definition of terms and the organization of the study.

Chapter Two orients the review of related literature, whilst Chapter Three focuses on the methodology of the study. The methodology describes the research design, the population, sample and sampling procedures, data gathering instruments, data collection procedures of the study, and the methods of data analysis. Presented in Chapter Four and Five, are the results of the study and the discussions of the findings respectively. Finally, the summary of findings, conclusions, recommendations and also suggestions for further research are embedded in the concluding chapter.

CHAPTER TWO

LITERATURE REVIEW

This second chapter presents an incisive and exhaustive review of relevant literatures on the concept of this project. It justifies the defined objectives and establishes the premise for the entire work. Basically, it comprises the Theoretical Framework of the Study, Review of Empirical Studies and Relevant Publications, and the Summary of the Literature Review.

2.1. THEORETICAL FRAMEWORK OF THE STUDY

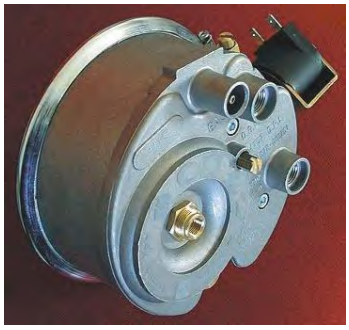
Spark ignition engines originally making use of petrol to empower automobiles can be converted to run on liquefied petroleum gas (LPG). Liquefied petroleum gas is a very clean fuel by comparison to petrol and diesel, with less vibration, longer engine life and reduced pollution to the environment.

Petrol vehicles or automobiles can be converted and equipped to run alternatively on liquefied petroleum gas (LPG) or petrol, or may exclusively be dedicated to run on LPG only. The choice of components necessary for the conversion of originally gasoline or petrol driven vehicles to liquefied petroleum gas usage depends on the originality of the vehicle design. Fuel injection systems vary slightly from carburetor systems, and may also be based on the make and model of the automobile. The general requirements for fuel injection and carburetor systems are hereby considered in this research.

2.1.1. CHOICE OF COMPONENTS FOR THE CONVERSION

According to Navitron (2013), features required for the conversion of carburettor or fuel injection systems to using LPG may include the main components as described in Table 2.1 below, and may be available in various sizes to match cylinders or tanks based on engine capacity:

Table 2.1. Features required for conversion to LPG usage

COMPONENT	APPLICATION	DESCRIPTION
 Electronic Vaporizer / Reducer	Required for both carburettor and fuel injection systems	By application of heat, the vaporizer converts liquid gas to vapour, automatically primes the engine when the ignition is on and regulates the flow of fuel in accordance with engine varying demands. Various types with idle and normal speed control adjustments exist. However, sensitive reducers may not need idle adjustment.
 LPG Solenoid Valve	For both carburettor and fuel injection systems	The LPG solenoid valve automatically shuts the supply of LPG fuel when the vehicle is switched to petrol

COMPONENT	APPLICATION	DESCRIPTION
 Petrol Solenoid Valve	Required for carburettor systems only	The petrol solenoid valve automatically shuts the supply of petrol when the vehicle is switched to LPG. Manual by-pass is incorporated to supply fuel in emergencies as when necessary.
 Switch Unit	For both carburettor and fuel injection systems	The switch unit permits the selection of fuel type. It signals the vaporizer when to provide LPG priming, and may also give indication of LPG fuel level, or alternatively, the reserve volume.
 Mixer	For both carburettor and fuel injection systems	The mixer provides the thorough mixing up of LPG vapour with air before getting into the inlet manifold.

COMPONENT	APPLICATION	DESCRIPTION
 Fuel Containers	For both carburettor and fuel injection systems	The fuel container or tank stores the LPG fuel. Containers are commonly available as cylinders or toroidals, thus, doughnut shaped.
 Multivalve	For both carburettor and fuel injection systems	The multivalve has several functions. It provides fuel take-off that prevents freezing up of the fuel tank. It permits filling of the tank through a non return valve and to a safe maximum limit of 80% of the tank's capacity. It is incorporated with mechanical and electrical shut-off facilities and LPG level gauge.
 Filler	For both carburettor and fuel injection systems	The filler provides the curvature through which refueling is done under high pressures. It is normally connected to the multivalve.

COMPONENT	APPLICATION	DESCRIPTION
 Airtight Box	Inside vehicle installation requirement	The airtight box is used to provide sealing against potential leakages, in particular, when the fuel tank is sited inside the vehicle
 Injection emulator	Required for some injection systems	Injection emulators are used to imitate the electronic management system of fuel injection vehicles to ensure effective operation.
 Backfire arrester	Recommended only for some vehicles	The backfire arrester prevents causing devastating damage to the system in the events of backfiring.

Source: Navitron (2013)

2.1.2. NATURE AND CONDITIONS OF SAFETY FEATURES OR DEVICES

The retrofitting requires four main classifications of components or features as:

1. Complete set of fuel container befitting liquefied petroleum gas (LPG) storage with valves and equipment to control the flow of fuel entering and leaving the container popularly known as the cylinder.
2. Fuel lock valve or filter and fuel lock to prevent the flow of fuel when the engine or the system is not working.
3. Vaporizer regulator or convertor to regulate the pressure at which the gas flows in accordance with engine varying demands.
4. An air/gas mixer to measure and meter air and gas flows in the right proportion according to mass or volume into the engine.

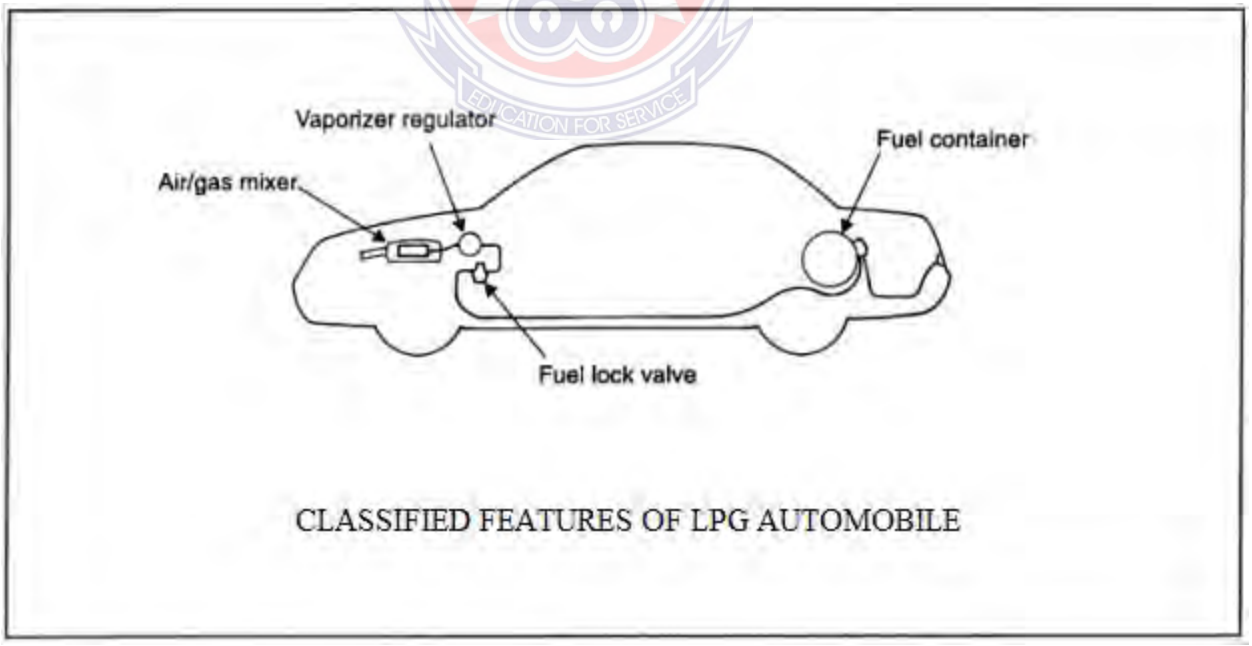


Figure 2.1. Ideal locations of main classified components of converted LPG automobile

Source: Workcover Authority (1998)

The ideal locations of the main classified components are shown in Figure 2.1. In this development, the LPG valves should not be mounted on thermoplastic dumper bars that have the tendency to dislodge easily in an event of accident.

The container that stores liquefied petroleum gas (LPG) for automobile's usage as fuel is a tested pressure vessel purposely designed and constructed in accordance with International safety Standards. The weld affected areas and the entire cylinder is subjected to controlled heat treatment and stress relief right at the manufacturing process. It is therefore hazardous and not recommended to subject this container to any form of welding, soldering, brazing or extreme heating after its manufacture. This pressure tank must be securely affixed to the vehicle, and where sub-compartment of the container is required, it must be so constructed such that any leakage of gas from any fittings cannot find its way into enclosed areas such as the passenger and luggage compartments. Also, in no account should the sub-compartment of a gas container be removed from the cylinder even if the two are mounted separately.

Remote fill containers have their fittings enclosed in a gas tight sub-compartment and their filling connections are remote from the container as shown in Figure 2.2. The filler valve is usually mounted on an external body panel and is connected to the container by a pipe protected and sealed in a heavy duty conduit. A vent is fitted to the sub-compartment such that any accumulated vapour of fuel will drain away outside the vehicle.

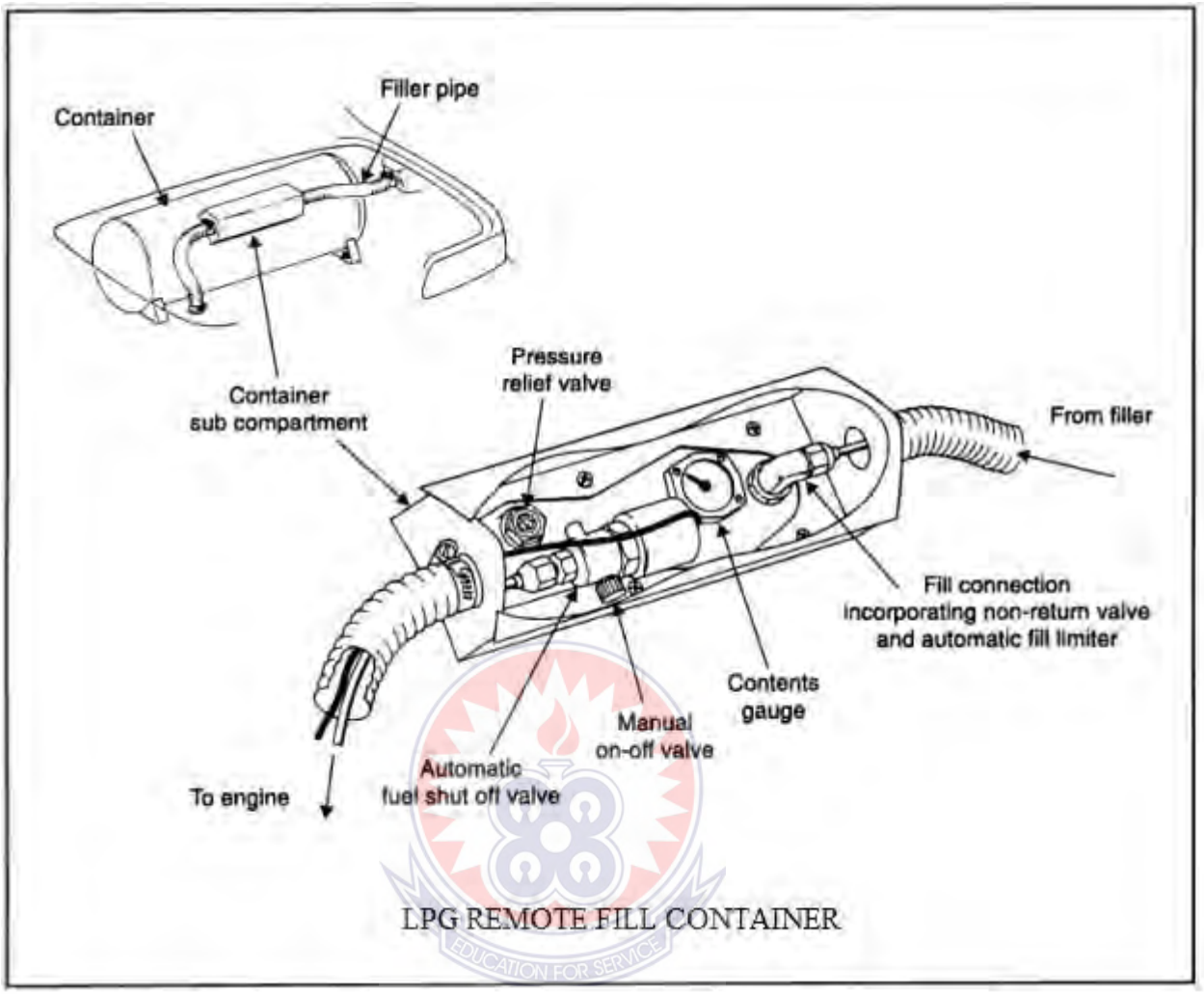


Figure 2.2. LPG fuel remote fill container arrangement

Source: Workcover Authority (1998)

Direct fill containers, as indicated in Figure 2.3, have their filler nozzle connected directly to the filler valve mounted on the container located inside the body shell in most cases. In this design, the passengers' compartment must be completely sealed from the space occupied by the pressure vessel. A vent must also be provided at the lowest point to permit any leakage of gases to escape.

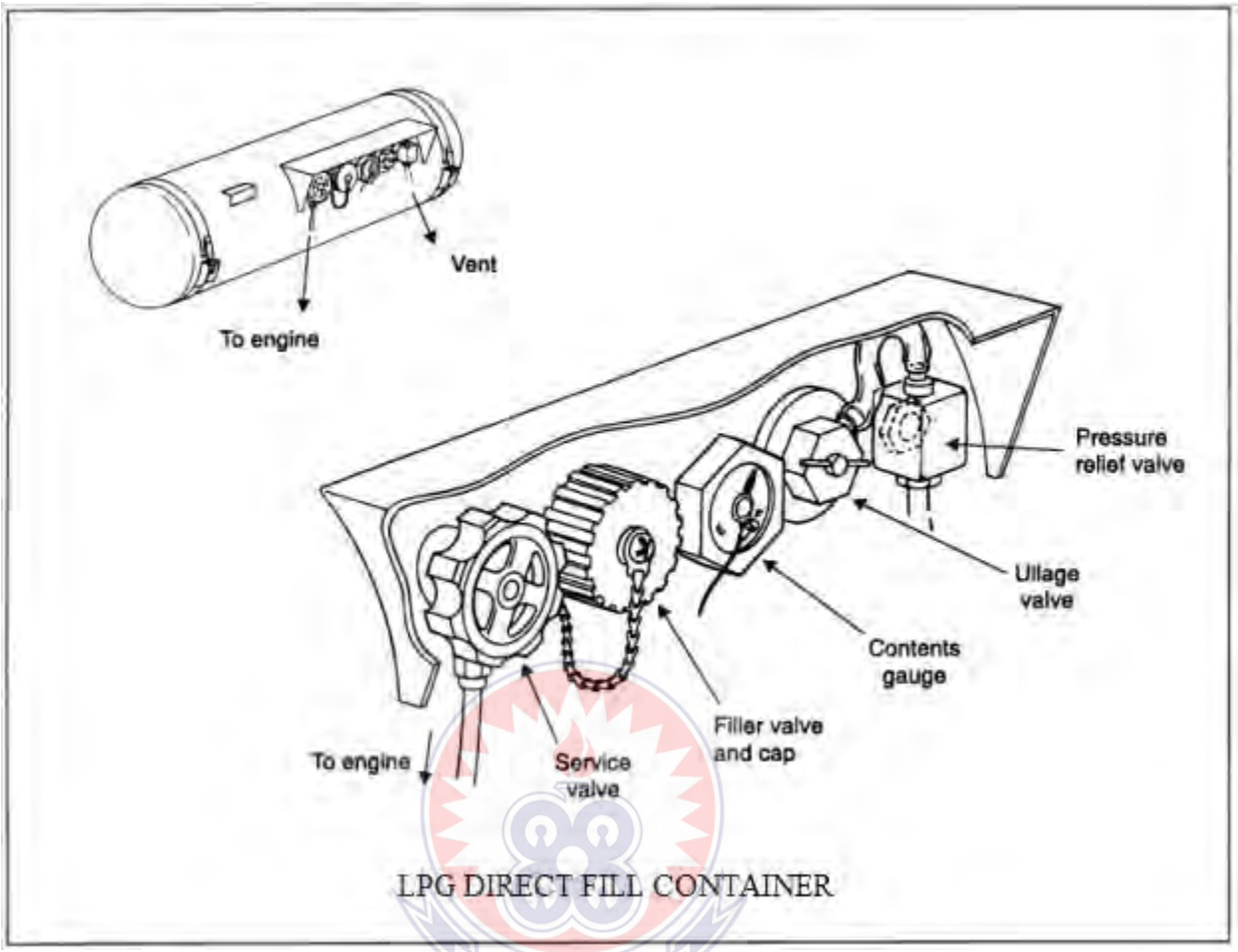


Figure 2.3. LPG direct fill container arrangement

Source: Workcover Authority (1998)

Direct fill containers that are mounted in the boot of a vehicle, must necessarily have the boot sealed off from the passenger's compartment to safeguard against asphyxiation.

As a preventive precautionary measure associated with the use of liquefied petroleum gas (LPG) on automobiles, any electrical device or apparatus, such as electric windscreen wiper motors, electrically operated radio aerials, electric fuel pumps or stereo systems must not be fitted in the same vicinity occupied by the fuel container.

Automatic fuel shut-off device is required as an additional safety measure, set to automatically prevent the flow of liquid fuel to the service line and the vaporizer, unless the ignition switch is on and the engine working. Retro-fitting automatic fuel shut-off device is highly recommended and encouraged. It must necessarily be located near the fuel container in a protected vantage point and can however be incorporated in the service valve (Workcover Authority, 1998).

A fundamental schematic diagram shown in figure 2.4 is a dedicated LPG fuel supply system of automobile. It comprises safety features, among others as, the Excess flow valve, Non-return valve also known as Check valve, Pressure relief valve otherwise referred to as Safety relief valve, and Manual shut-off valve known as Service valve.

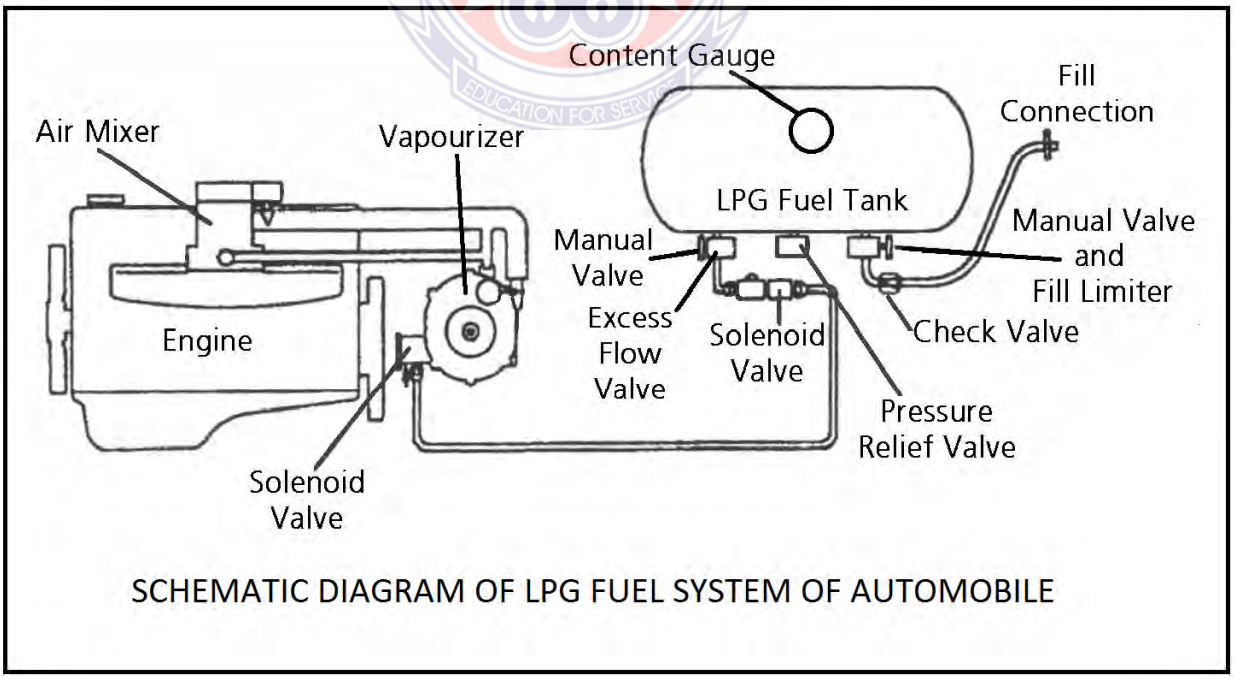


Figure 2.4. Schematic diagram of LPG fuel supply system of automobile

Source: Gas Authority (2011)

The Excess flow valve is installed at the exit of the LPG fuel tank. It is set to be in the open state and automatically closes when the flow in a given direction exceeds predetermined limit under abnormal conditions as pipe ruptures, in order to avoid leakage.

The Non-return valve is a unidirectional flow device located at the entrance of the LPG fuel tank as well as the filling connection to the vehicle body to permit fuel flow in only one direction. In the event of accident, it prevents the tendency of backflow of fuel.

Pressure relief valve is one of the safety devices, connected to the vapour space of the fuel tank. It discharges to the atmosphere automatically when pre-determined pressure inside the fuel tank is exceeded to relieve the tank from undue pressures. It as well relieves the fuel tank of excessive pressures in the event of accidents that may lead to fire and or explosion.

The Manual shut-off valve is a Service valve, provided at the outlet connection of the fuel tank. It is manually operated to shut down fuel supply from the tank in the events of accident, maintenance and parking of vehicle for long periods of time. (Gas Authority, 2011)

2.1.3. EFFECTIVE OPERATION THAT ENSURES SAFETY

Workcover Authority (1998), intimated as pollution control requirements that equipment such as catalytic converters, emission and engine control systems of vehicles originally operating on unleaded petrol must remain operational in the conversion process. With vehicles converted to use both petrol and liquefied petroleum gas, the emission control systems, fuel emission systems, engine control and management systems, including all relevant devices, catalytic converters and

oxygen sensors, that are originally incorporated, must remain functional. Air cleaner, carburetion and injection modifications may require precautionary retrofits.

Where the installation of LPG equipment requires major chassis and body structural alterations, vehicle structural strength may be tampered with. As such, recommended engineering signatory approval must be acquired.

Unless specific approval is given by authorizing organization, it is illegal to use automobile liquefied petroleum gas in cylinders for any other purposes other than for fuel.

On no account should LPG fuel container be situated in the engine compartment, although some vehicles have theirs on the roof with appropriate mountings, this arrangement will not augur well with a converted vehicle. Navitron (2013), directed in his Conversion Manual that the tank may be fitted inside the boot, underneath the floor of the boot, in the spare wheel well or contained within the chassis of the vehicle and protected against the events of crash.

Straps used to mount LPG tank longitudinally are not usually strong enough to retain the tank in the event of impact. When mounted in longitudinal manner, especially in the boot where there is limited clearance between the tank and the rear of the vehicle, the tank will not crumple on impact and may result in severe injury to rear seat occupants. Transversal mountings are therefore generally recommended.

Any tank mounted inside a vehicle, should have its multivalve sealed-off in a manner that vents potential leakage of vapour to the outside of the vehicle to avoid suffocation of occupants.

When mounting from underneath the vehicle and far from an axle, a minimum ground clearance of 250millimeters should be allowed to prevent grounding on speed ramps.

Figure 2.5. Multivalve angular measurement

Source: Navitron (2013)

Description of multivalves is in accordance with their fitment angles and the tank size to fit, when the multivalve is designed to be part of a tank as a combination. The tank must therefore be orientated at manufacturer's specified angle, using appropriate angle gauge, to enable the float in the tank to operate correctly to ensuring 80% level safety shut off of fuel when filling the tank. Wrong angled multivalve situation will prevent the safety level shut off mechanism from working appropriately. It is therefore recommended to adhere to manufacturer's specification when mounting the tank for the best result. The multivalve angular measurement is as depicted in Figure 2.5 above.

An airtight box, when required as in inside vehicle mounted tanks, should sandwich between the valve and the tank.

Figure 2.6. Compression tee (T) fitting

Source: Navitron (2013)

Extra fuel capacity means wider range of travel before a full tank gets exhausted. The use of a single large fuel tank on a vehicle to achieve extra capacity and range may be impracticable and infringe unacceptably on luggage compartment, posing lots of inconveniences. As such, additional fuel tanks may be mounted at vantage points to achieve extra fuel capacity and range. In this development, compression tee (T) fittings typically shown in Figure 2.6 is recommended at the junction of the filler lines of two tanks and each tank fitted with electronic shut-off solenoid to prevent siphoning fuel from one tank to another that may potentially exceed the safety maximum fill. Fuel starvation of the engine on steep hills associated with partially filled tank could be avoided by locating the multivalve at the rear of the vehicle.

Multivalve potential leakages must be ducted to the outside of the vehicle when the tank is located within the vehicle which without could suffocate the occupants. The fuel lines connecting the filler, the vaporizer and the multivalve with the help of airtight box must be isolated from the vehicle by containment within plastic ducting as appropriate. Figure 2.7 samples the containment ducting with the aid of an airtight box on a cylinder mounted within the vehicle.

Figure 2.7. Containment ducting with the aid of airtight box on a cylinder

Source: Navitron (2013)

Various options of filler mountings exist. As much as they must be designed to be less invasive, they necessarily have to offer easy access for filling. Notable among optional mountings, some of which can be seen in Figure 2.8, are on a towbar, in the bumper or through the bulkhead.

(a) Filler mountings *(b) Bulkhead mounting* *(c) Towbar mounting*

Figure 2.8. Options of filler mountings; (a) Filler mountings, (b) Bulkhead mounting, (c) Towbar mounting

Source: Navitron (2013)

Varieties of approved materials could be used in the construction of fuel lines. However, it is preferable to use sheathed copper pipe of 6mm diameter to run from the multivalve to the LPG solenoid at the front of the vehicle and 8mm copper pipe to run from the filler to the multivalve. Unnecessary joints in fuel lines must be avoided. Thus, all fuel lines connecting components in the fuel system should be a single continues piece of pipe. Tanks mounted inside vehicles should use 8mm diameter copper airtight box, and 6mm copper pipe to connect the multivalve and LPG solenoid. No fuel line should be permitted to run through the inside of the vehicle, but along the underside.

Scratched pipes should not be used since they are termed stress raisers to breakages or failures. They should duly be replaced when identified. The use of proprietary sealing compound is highly recommended to significantly reduce failure rate of joints to components.

As much as practicable, all fuel lines, at least, should be separated 250mm away from vehicle exhaust system, and be secured at 600mm regular intervals.

The fuel line should be immediately coiled against vibration before connecting to the LPG solenoid valve. The same anti vibration coil should be arranged between the LPG solenoid valve and the vaporizer. For the best results, the coil diameter should range between 50mm and 75mm.

Accelerating and braking forces of the vehicle may affect sensitive diaphragms in the vaporizer. It is therefore recommended to mount the vaporizer to the side of the inner wings, and in the same plane as the vehicle such that the driving forces may not affect the diaphragms. If high cornering forces are expected, the vaporizer must then be mounted horizontally.

Unless the vaporizer uses electrical heater to perform its functions, check it against coolant leakage and tighten joints if necessary. Ensure that the vaporizer warms up to engine temperature, and there are no pockets of air preventing warm water circulation through it.

There should be a simple power valve device, as in Figure 2.9, arranged between the vaporizer and the mixer to save as adjustable restrictor to limit the maximum flow rate of LPG fuel.

The LPG Solenoid should be mounted in a position where it will be protected in the event of an impact. The most suitable location is on the bulkhead at the rear of the engine bay or recess.

(a) Front view of power valve

(b) End view of power valve

Figure 2.9. Elevations of Simple Power Valve; (a) Front view of power valve, (b) End view of power valve

Source: Navitron (2013)

Carburettor equipped vehicles should have electric petrol solenoid to shut-off petrol supply when the vehicle is switched to run on LPG. The use of non-return valve on carburettor systems with fuel return pipe is recommended. With fuel injection systems, the petrol solenoid valve is not required instead LPG solenoid valve should be used.

One of the most critical decisions in the LPG conversion is the choice and positioning of the mixer to make the vehicle drivable. The choice depends on the venturi size and the location is preferably as close to the mouth of the carburettor as practicable, to enhance the sensing of the engine load.

Unless otherwise specified, fuel injection systems have the mixer normally located directly at the air inlet side of the throttle body with the intension to minimize potential backfiring related

problems. Antibackfire flap is recommended in some systems to orient the correct opening of the airflow flap in normal operation.

The opening of the inlet valve during the course of operation of the engine, allowing burning gases of fuel and air entering the inlet manifold, setting fire to the explosive mixture of fuel and air with damaging consequences is referred to as backfiring. Its devastating force depends on the volume of mixture in the manifold. This situation arises if for any reason the charge in the combustion chamber fails to ignite at the correct time, mainly due to ignition faults. It is crucially paramount that the ignition system is kept in good working condition, and any symptoms of faults investigated and rectified at the earliest opportunity.

Some fuel injection systems like L-Jetronic should have the mixer placed downstream of the air flap meter, to prevent over-choking on start-up. The air flap meter is very delicate and so to prevent its damage occurring in the event of backfire, a blade saver exclusion device should also be used.

Systems with premapped injection for tickover employ air-bypass valve to correct fuel mixture that prevents erroneous adjustments. The mixer should therefore be located upstream of the air-bypass valve in order to avoid explosive backfiring.

The use of catalytic converter on LPG converted vehicles provides a cleaner exhaust. Its removal should therefore not be encouraged. Catalytic converter incorporated vehicles require variable

power valve which should be controlled by feedback from lambda sensor. To prevent destruction to the converter through over fuelling as a result of extended periods of excessively rich mixture, the standard adjustable power valve should be replaced by electronic unit and to be controlled through stepper motor by the control unit. Throttle position sensor for extra control of fuel mixture should also be catered for by this arrangement. Correctly instituted feedback system improves vehicle performance and fuel economy as compared to a fixed power valve system.

Electrical connections of a conversion should be in accordance with authorized wiring diagram. Wiring installations should be harnessed as much as practicable in a tidy fashion. Unapproved quick fit connections should be avoided. All joints should be soldered and insulated with heat shrink insulation. All cables should be kept as short as practicable. Current supplying cables should be fused. All joints, electrical connections and units should be mounted at vantage points to prevent water or liquid related interferences.

Carburettor vehicles should incorporate electric petrol solenoid to switch off petrol supply to the carburettor when LPG fuel is in use. It should be situated between the mechanical fuel pump and the carburettor. Vehicles with electric fuel pumps may incorporate relay in the wiring of the electric petrol pump to possibly switch off the fuel. A non-return valve should be incorporated in the fuel return line to prevent the occasional siphoning of petrol fuel whilst LPG is in use.

Some carburetors, notably Solex carburetors, incorporate electronic shut-off valves that prevent over running of fuel when the ignition is switched off. The device can also be used for shutting off petrol supply when running on LPG, but characterized with valve seizure problems that need to be checked regularly.

Petrol injectors need be shut off when running on LPG. With injection systems making use of electronics, it is relatively easier shutting down petrol injectors. This is achieved by incorporating additional relay into the injection control system, which should be controlled by the fuel changeover switch.

To ease installation and efficiency on modern vehicles, injection emulators are incorporated to:

1. Disconnect power to the petrol injectors when running on LPG.
2. Check and compensate the electronic control unit to ensuring effectiveness and efficiency when the injectors are disconnected.

The emulator simply cuts off the injectors but continue to provide residual current to the electronic control unit to ensuring effectiveness and efficiency, however, emulator may not be needed when the injectors are not designed to fire sequentially.

Three types of injectors are used on vehicles:

1. Mono injector – which is also referred to as ‘electronic carburettor’.
2. Common earth injector – implies the injectors are connected to share a common earth.

3. Sequential injector - each injector is independently wired.

A fuel system in which each injector is earthed separately is referred to as sequential injection system that requires injection emulator to enhance performance. Mono and common earth injection systems can simply have their injectors shut off by using a relay. However, special mono emulator also exists. Location of injection emulator should be devoid of ingress of water. Wiring up injector emulator is a daunting task. Care must be taken to solder in emulators to make them problem free, taking into consideration colour coding and circuit diagrams, not forgetting manufacturers' specifications.

When fuel mixture is badly set up in vehicles equipped with catalytic converters, it is possible to damage the catalytic converter. However, it is recommended to take advantage of lambda probe to constantly recalibrate the system for maximum power and efficiency. Instituting variable stepper motor power valve in the fuel line between the mixer and the vaporizer to electronically set up the fuel mixture enhances the reliability of the system.

Causes of backfiring could be traced down to one of the following:

- Vacuum leakage of fuel system
- Too lean fuel strength
- Incorrect mixer size for a given system

Mixer position could prone a vehicle to backfiring. The intensity of the backfiring explosion depends on the quantity of fuel mixture stacking between the mixer and the engine. Protection

devices such as a bladesaver or a boxsaver, better still backfiring arrester should be used to check the menace (Navitron, 2013).

2.2. REVIEW OF EMPIRICAL STUDIES AND RELEVANT PUBLICATIONS

A study on LPG as a fuel for vehicles and government policies on automobile liquefied petroleum gas usage form the review of empirical studies and relevant publications as follows:

2.2.1. A STUDY ON LPG AS A FUEL FOR VEHICLES

Research reveals on LPG as fuel for vehicles by Liu, Yue and Lee (1997), have it that, since 1912 LPG had been in use as a fuel for vehicles. It was on limited bases initially but increasing becoming popular in 1970s and 1980s when some countries like the US and Canada tried to reduce their dependence on crude oil. Demand for the fuel was however boosted in the 1990s by rising environmental concerns.

Liu et al (1997), discovered in their studies that LPG is mainly used by light vehicles and in particular taxis. It is also applicable to vans, buses and trucks. They further explained that:

Vehicles converted to use LPG can be dual-fuel or flexi-fuel. Dual-fuel vehicles have two separate fuel systems, with only one fuel being used at a time. In contrast, flexi-fuel vehicles have one fuel system operating on a mixture of fuels. Dual fuel vehicles and flexi-fuel vehicles allow LPG to be used in parallel with other fuels. (para. 9).

The main source of air pollution, in urban areas in particular, is vehicles emission. In some countries, government encouraged the use of cleaner alternative fuel as liquefied petroleum gas (LPG). It is predominantly composed of simple hydrocarbon compounds and therefore cleaner than petrol and diesel. It contains very little sulphur and free from most additives.

LPG vehicles emit lower levels of hydrocarbon compounds (HC), nitrogen oxides (NOx), sulphur oxides, air toxics, and particulates when compared with petrol and diesel driven vehicles' emissions.

As a result of technological progress, the environmental merit of LPG over petrol and diesel is getting smaller. The use of three-way catalytic convertors, and reformulated petrol and diesel reduce their negative impact on the environment considerably. The three-way catalytic convertors lessen emissions of carbon monoxide (CO), hydrocarbon compounds (HC) and nitrogen oxides (NOx) of petrol driven vehicles.

The efficiency of an engine depends on its compression ratio basically. Other measures could however be considered, but the higher the compression ratio the more the efficiency. The efficiency of LPG engine is similar to that of petrol. Meanwhile, both types are not as efficient as diesel engines. Diesel engines have much higher compression ratios and are therefore more efficient.

For the same mass and volume of fuel, diesel vehicle travels longer distance than an LPG and petrol vehicles. Diesel engines also conserve energy far better than LPG and petrol engines. With the same mass of fuel, LPG vehicle travels longer distance than petrol but shorter distance than petrol with the same volume of fuel.

In terms of power output and torque development, the performance of LPG engine is similar to that of petrol engine.

LPG as a byproduct of petroleum and natural gas is obtainable from two sources, notably the refining of petroleum and the extraction of natural gas. LPG refined from petroleum is estimated between 10% and 15% of the quantity of petroleum. Extraction from natural gas is estimated to 3% of the quantity of natural gas. As such, the availability of LPG is not as common as petrol.

The steady supply of LPG and at a stable price is some of the factors encouraging consumers to convert to the fuel usage.

LPG has a wider flammability limit than both petrol and diesel. Fire or explosion occurs at times when an LPG vehicle is involved in accident. Explosion occurs when there is adequate presence of LPG fuel and air, ignited to generate considerable heat and rapid air movements within the shortest possible period of time. If for any reason the buildup of heat is gradual, the resulting effect will be fire rather than explosion.

Allowing LPG to accumulate in an enclosed environment is dangerous in the sense that it is denser than air and will sink to accumulate. Its evaporation is very rapid, and expands 270 times its volume in the liquid state. Due to its quick displacement of oxygen characteristic, asphyxiation is inevitable when leaking in an enclosed environment with humanity.

Human factor is crucial in ensuring safety with LPG usage, that is to say human error was the major cause of accidents involving LPG vehicles. Human error category accidents generally involve careless fuel handling and faulty workmanship including poor sealing of bodywork around remote refueling connectors and its likes.

To be motivated to use LPG or not, consumers will necessarily have to consider the following cost:

- Capital cost;
- Maintenance cost; and
- Fuel cost.

Capital Cost is incurred when purchasing LPG vehicles originally produced by manufacturers or converting petrol or diesel driven vehicles to using LPG as fuel.

Maintenance cost for LPG driven vehicle is lower slightly than for petrol or diesel driven vehicles. Essentially, LPG does not wash way lubricant from cylinder walls of the engine as

gasoline and diesel do which is detrimental to the engine and impede efficiency. Maintenance requirements and cost are also reduced by the cleaner burning characteristics of LPG fuel.

Initial cost of obtaining an LPG fuel vehicle may be a factor in this choice, but its running cost can be much lower than petrol or diesel vehicles depending on government policy, especially on fuel tax.

2.2.2. GOVERNMENT POLICIES ON AUTOMOBILE LIQUEFIED PETROLEUM GAS USAGE

To enhance safety in the usage of Liquefied Petroleum Gas (LPG) as fuel, regulations or codes of practice, as Liu et al (1997) put it, are introduced by Government Policies to regulate the safe handling of LPG, the use of LPG vehicles, the design and construction of LPG fuel tanks as well as imposition of restrictions on LPG filling stations, requirements for regular inspection of LPG vehicles and proper training of personnel handling LPG in general and for vehicles.

Policy regulations governing the fuel system of LPG vehicles is basically to prevent leakage of fuel, minimizing the possibilities of accidents and reduce damage in the events of accidents. Some of these requirements have it that:

- The Conversions should be done by authorized personnel;

- Regular inspections including checking of LPG leakage within the fuel system should be done by approved technicians;
- Materials and thickness of fuel tanks should follow approved specifications;
- Various parts of the fuel tanks should follow specifications, and to include devices such as liquid level indicator, overfilling prevention device, safety relief valve and emergency shut-off valve;
- LPG fuel tanks should be filled not to exceed certain specifications. Thus, 80% for US, 80% to 85% for Netherlands and 85% for Japan standards respectfully;
- LPG vehicles should pass barrier collision and fire test requirements.

Adequate training of personnel to handle LPG is crucial to ensuring safety in the usage of liquefied petroleum gas. The requirement in most countries is that, the operating staff of filling stations as well as repair and maintenance staff should be adequately trained and duly registered.

Industrial associations play vital roles in the training of personnel handling LPG and monitoring of standards with regards to LPG usage. Such associations as the National Automotive Gas Association of Japan, Japan LPG Association, and the Australian Liquefied Petroleum Gas Association among others exist. As such, comprehensive sets of rules have been developed concerning the safe handling of LPG, and the strict compliance of these rules ensures safety.

2.3. SUMMARY OF LITERATURE REVIEW

Conversion of petrol originated automobiles can be equipped to run alternatively on liquefied petroleum gas or petrol. Exclusively, it can be dedicated to run on LPG alone. The choice of components depends on the originality of the vehicle.

Both carburettor and fuel injection systems require Electronic Vaporizer or Reducer, LPG Solenoid Valve, Switch Unit, Mixer, Fuel Container, Multivalve and Filler. Petrol Solenoid Valve is required for Carburettor systems only whilst Injection Emulator is required for some injection systems. Airtight Box is a requirement for inside vehicle fuel tank installation and Backfire Arrester a recommended feature only for some vehicles.

The nature and conditions of safety features or devices as listed below is a prime factor to ensuring safety in the LPG conversion practice:

1. Fuel container or tank
2. Fuel content gauge
3. Overfilling prevention device
4. Pressure relief valve
5. Automatic fuel shut-off device
6. Manual shut-off valve
7. Non return valves
8. Vents permitting leakage of gases to escape
9. Airtight box or any approved form of sealing

10. Excess flow valve
11. Catalytic converter
12. Electrical relay, and
13. Backfire arrester

Most of these features, if not all, must form part and parcel of the LPG fuel system and in good working conditions to meeting International Safety Standards and Compliance. The fuel container or tank is a pressure vessel, the main potential source of danger. Its features and location must therefore conform to specification for uttermost safety.

For effective operation that ensures safety, the conversion should be down in accordance with the conversion manual's specifications and must be carried out by competent and authorized personnel. There must however be regular inspections and maintenance to constantly revitalize the functions of the system.

CHAPTER THREE

METHODOLOGY

The concept of the methodology provides information on participation of the research and the sample techniques, procedures and equipments used in data collection and analysis. The subsections of the chapter basically include Research Design, Population, Sample and Sampling Procedures, Instruments used, Data Collection Procedures and the Methods of Data Analysis.

3.1. RESEARCH DESIGN

In view of the purpose of the study that seeks to address vehicular problems in connection with liquefied petroleum gas usage as fuel for converted automobiles, and has to do with practicalities on the ground relating to literature, descriptive research method is seen most appropriate to ease work on the research objectives of the study. Descriptive survey, as Agyedu, Donkor and Obeng (2011) imply, seeks to gather information on standards about a concept to describe the realities in practice. It describes phenomena as they exist or that which portray an accurate profile of persons, events or situations. It is usually used to identify and obtain information on the characteristics of a particular problem or issue in a given situation. In this vain, it can conveniently be utilized to scrutinize and evaluate the research questions formulated on the concept of LPG conversion. As such, cross sectional descriptive survey with observation guide and interview schedule is used to provide pragmatic answers to the research questions.

3.2. POPULATION

Vehicular population as the element of the study is targeted at light commercial vehicles operating on liquefied petroleum gas in the Ho Municipality. According to the Driver and

Vehicle Licensing Authority (2013), population of registered converted vehicles stood at 1,755 as at July, 2013 covering a period of five years' registration. Research carried out at all lorry stations and their invariance including workshops in the Ho Municipality on market and non market days revealed the number could be the true reflection of the situation on the ground. Some vehicles notably taxis do not load at any lorry stations but eventually find their ways in the invariance of these stations. Such vehicles are also equally taken care of in the study. Currently, the Municipality is characterized with about 4,968 vehicles in general within an area of 20,570 square kilometers.

3.3. SAMPLE AND SAMPLING PROCEDURES

The researcher has made use of a random sample size of 212 converted vehicles representing 12.08% of the total 1,755 targeted vehicular population. This sample size was deemed fit in view of Agyedu et al (2011), in their confirmation of the fact that for a population of few thousands a sample size of 10% is adequate for meaningful analysis and interpretations. It was also emphasized that for a descriptive research, 10 to 20 percent sample size will be necessary (Ary, Jacobs & Razavieh, 1979). Again, it was noted that the larger the sample size, the more reliable and valid the results based on it will become. As such, 12.08% sample size of the population is therefore seen as a reasonable proportion for the generalization of the studies.

The breakdown of the sample size of 212 comprises stations and other locations of vehicles on the streets of Ho. Thus:

- Ho main station 32.08%, (68)
- Metro bus station where some light commercial vehicles could be found loading 5.19%, (11)

- Tanyigbe/Shia station 4.25%, (9)
- Sokode/Tsito station 6.13% (13)
- Adaklu/Adzidome station 3.77% (8)
- Kpenoe/Takla station 1.42% (3)
- Klefe/Ziavi station 1.89% (4)
- Vehicles plying the streets of Ho without any specific allocation of station including those found at workshops 45.28% (96)

The exercise was carried out mainly on market days where vehicular population was found to be on its pick in the Ho Township. However, enough time was spent at workshops and on non market days to examine these vehicles critically since some of them were less busy on these days. Only those vehicles that were presumably roadworthy but having minor problems were examined at workshops. Any exiting station that has not been mentioned forms part of one of the above listed ones to facilitate work on the research.

Due to the heterogeneous nature of the lorry stations or locations but having definite strata or groupings which are homogenous, the sampling technique employed by the researcher is the stratified random sample method making use of the proportionate stratified random sample. It buttresses the point that, the main intention of the study is not to compare and contrast happenings of the various stations but rather to have a fair representative sample of the entire population. In each station, the subtotal number of vehicles was taken and the equivalence sample size deduced using the simple random sampling approach. Table of random numbers was used at stationary stations whilst lottery method applied for vehicles found at workshops and on

the streets without definite allocated stations. In the lottery case, any vehicle found on the streets of Ho utilizing liquefied petroleum gas as fuel was selected, since it was very difficult to locate the subtotal number of vehicles of this stratum.

3.4. INSTRUMENTS

The nature of the research topic demands extensive coverage, for which Observation Guide or Schedule and Detail Interview Schedule Instruments were designed for the data collection.

The Observation Guide or Schedule of the Participant Observation research technique was used to prevent the possibility of gathering extraneous data or impression. Detail Interview Schedule of the Structured Interview technique was also utilized as an additional resource for the purposes of personal contact, high rate of response, clarification of issues and probing of specific meanings of responses.

The research instruments were integrated as one document and subdivided into three parts. The preliminary stage formed the first part that dealt with introductory message and basic information about the vehicle to be examined. The Observation Guide Instrument was contained in the second part whilst Interview Schedule Instrument occupied the third part.

Twelve criterion questions were listed in all, two for Observation Guide and eight for Interview Schedule. The Observation Guide probed the components necessary for the conversion of originally gasoline or petrol driven vehicle to liquefied petroleum gas usage and the nature and conditions of the safety features or devices used on the liquefied petroleum gas automobile. The

Interview Schedule Instrument sought to find how the conversion was done for effective operation that ensures safety. The type of items and their responses ranging from Dichotomous response, Multiple choice, Rating, and Open-ended Items, all of which meant for qualitative research according to Agyedu et al (2011), are shown in appendix E.

3.5. DATA COLLECTION PROCEDURES

Having constructed the research instruments of the study, the researcher obtained the population of registered converted LPG automobiles in the Ho Municipality from the Driver and Vehicle Licensing Authority (DVLA) in Ho. The copy of the instruments was then produced to the number of the sample size. The researcher personally consulted each sample unit, introduced himself and the intension for the study. The researcher made it point blank that:

By the nature of assurance and built up of rapport, permission was granted in each case to interview, observe, and take photographs where necessary. The researcher personally recorded the outcomes to fast truck the entire exercise of data collection.

3.6. METHODS OF DATA ANALYSIS

To make meaning out of the data collected, its analysis was carried out to facilitate interpretation of the results and drawing of conclusions. Editing of the data collected went on to ensure consistency of the responses by critical examination with regard to the problem, purpose and the

research questions of the study, checking for accuracy, consistency, relevance and appropriateness of all responses. The researcher properly, exhaustively and adequately categorized the data to set the stage for coding. The different categories were mutually exclusive such that they were distinct, independent and not overlapping. Coding of raw data went on after completion of categorizations to translate the raw data into a form that could be counted, tabulated or fed directly into a computer. Recording on data summary sheet was done respondent by respondent. Tabulation of data in orderly arrangement, columns and rows was made to summarize the massive data into a compact form that facilitated comparisons, and brought out relations existing within the data collected. Themes, concepts and observational data of the research were then analyzed using descriptive statistics as recommended by qualitative research.

Tables, Histogram, Bar chart, Pie charts and the usual direct descriptive meanings of responses were expressed as percentages and used finally to facilitate interpretation of results and drawing of conclusions in answering the research questions formulated. A Factor of safety deduced as the ratio of the sum total scores over the sum total expectations expressed as percentage and pegged at 60 percent, below which the feature being examined was considered unsafe and vice versa.

CHAPTER FOUR

RESULTS OF THE STUDY

The outcome of the research is presented in this chapter. Prose, tables, figures and graphs are used to explain the concept under the subsection termed the Background Analysis of the Data, taking in to consideration the three research questions of the study.

4.1. BACKGROUND ANALYSIS OF THE DATA

The three research questions formulated to aid the research were broken down to twelve criterion questions in all, concerning the availability of the required Components of the LPG converted automobiles, the nature and conditions of safety features or devices of the conversion practice, and other essential constructional and operational conditions that ensure safety of the LPG converted automobiles operating in the Ho Municipality. These questions had been answered one after the other with their appropriate data.

Out of the sample size of 212 of various makes and models of liquefied petroleum gas converted automobiles audited, 165 representing 78 percent were using carburetor and 47 representing 22 percent making use of fuel injection system. Also, LPG dedicated automobiles stood at 98 representing 46 percent whilst 114 automobiles representing 54 percent were using dual fuel, thus, petrol and liquefied petroleum gas alternatively.

4.1.1. THE CHOICE CONVERSION COMPONENTS:

How is the components necessary for the conversion of originally gasoline or petrol driven vehicle to liquefied petroleum gas (LPG) usage chosen?

The criterion question of the first research question sought to find out the availability of the required components of the LPG converted automobiles and the results were as presented in Table 4.1.

Table 4.1. The availability of the required components of the LPG converted automobiles.

COMPONENTS OF LPG AUTOMOBILE	AVAILABLE		NOT AVAILABLE	
	Number	Percentage	Number	Percentage
1. Electronic Vaporizer or Reducer	212	100	0	0
2. LPG Solenoid Valve	203	96	9	4
3. Switch Unit	130	61	82	39
4. Mixer	212	100	0	0
5. Fuel Container	212	100	0	0
6. Multivalve	92	43	120	57
7. Filler	212	100	0	0
8. Petrol Solenoid Valve	59	28	153	72
9. Injection Emulator	28	13	184	87
10. Airtight Box	25	12	187	88
11. Backfire Arrester	21	10	191	90

Source: Field Survey (July, 2013)

4.1.2. THE NATURE AND CONDITIONS OF CONVERSION FEATURES:

How is the nature and conditions of the safety features or devices used on the liquefied petroleum gas (LPG) automobile?

Table 4.2 presents the nature and conditions of the safety features or devices probed by the criterion question of the second research question as a prime factor to ensuring safety in the LPG conversion practice.

Table 4.2. The nature and conditions of safety features or devices used on the converted LPG automobiles.

SAFETY FEATURES OR DEVICES	NOT AVAILABLE		VERY POOR		POOR		SATISFACTORY		GOOD		VERY GOOD	
	No	%	No	%	No	%	No	%	No	%	No	%
1. Fuel container or tank	0	0	17	8	20	9	120	57	30	14	25	12
2. Fuel content gauge	19	9	24	11	50	24	56	26	35	17	28	13
3. Overfilling prevention device	15	7	21	10	16	8	82	39	42	20	36	17
4. Pressure relief valve	0	0	0	0	18	8	45	21	60	28	89	42
5. Automatic fuel shut-off device	22	10	3	1	10	5	61	29	54	25	62	29
6. Manual shut-off valve	42	20	12	6	5	2	36	17	44	21	73	34
7. Non return valves	0	0	0	0	10	5	37	17	67	32	98	46
8. Vents for escape of gases	0	0	0	0	12	7	77	36	53	25	70	33
9. Airtight box or approved sealing	125	59	40	19	20	9	15	7	7	3	5	2
10. Excess flow valve	95	45	0	0	19	9	24	11	31	15	43	20
11. Catalytic converter	44	21	0	0	10	5	28	13	54	25	76	36
12. Electrical relay	180	85	0	0	3	1	10	5	7	3	12	6
13. Backfire arrester	191	90	0	0	0	0	3	1	12	6	6	3

Source: Field Survey (July, 2013)

4.1.3. CONVERSION FOR EFFECTIVE OPERATION:

How is the conversion done for effective operation that ensures safety?

In a quest to find out how many catalytic converters were operational after the conversions, 168 representing 79 percent were functional, while 44 representing 21 percent were not operational.

The 44 catalytic converters representing 21 percent were either disconnected or were not part of the system design. No information about the removal of Emission and engine control systems, Emission control systems, Fuel emission systems, Engine control and management systems, and Oxygen sensors were however retrieved.

In Figure 4.1, the situation of LPG fuel containers at various locations of the automobiles are shown in exploded pie chart to enhance understanding of what transpired at the field.

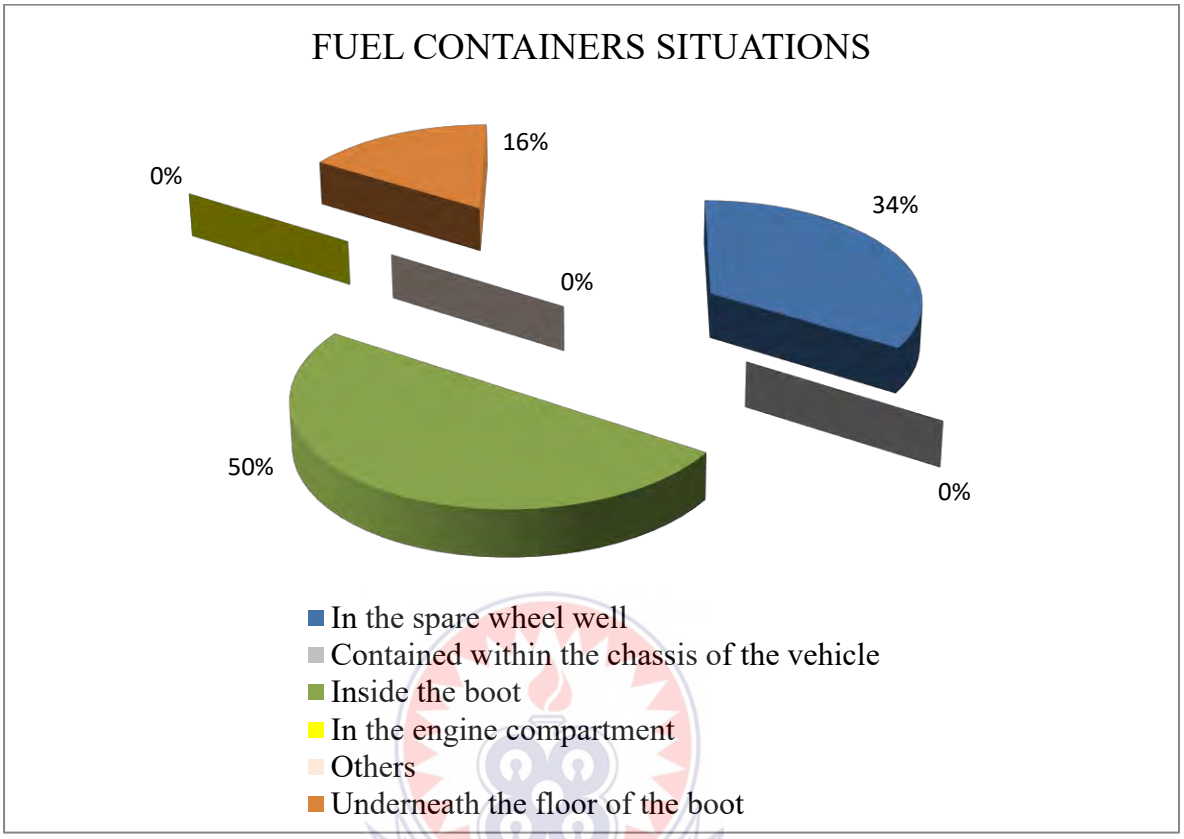


Figure 4.1. Situation of LPG fuel containers on vehicles.

Source: Field Survey (July, 2013)

Depicted in Figure 4.2, is the levels of fullness that the safety shut off of fuel devices of vehicles come to operation when filling the tank.

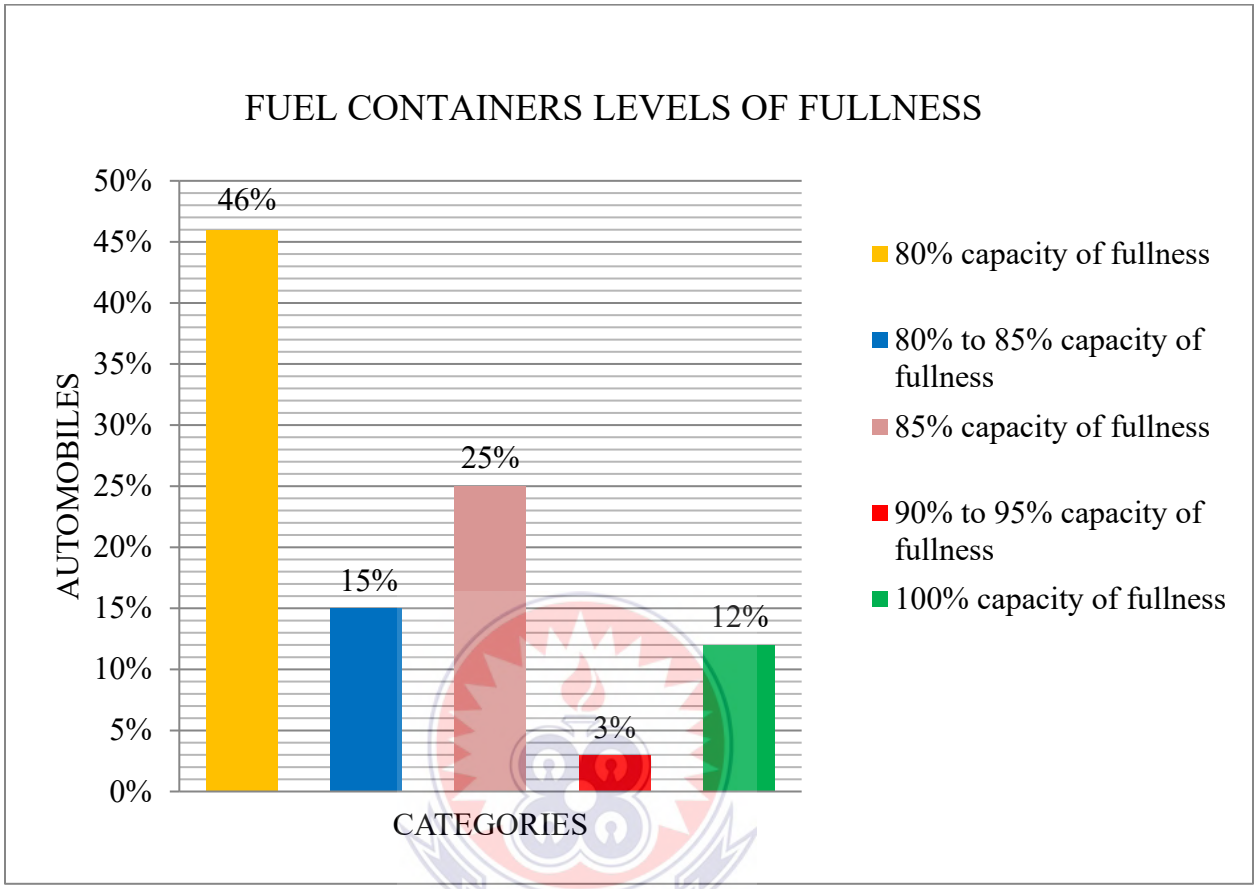


Figure 4.2. Levels of fullness that the safety shut off of fuel devices of vehicles come to operation.

Source: Field Survey (July, 2013)

Showing in Figure 4.3, is the distribution of how suffocation of occupants by fumes from inside vehicle mounted containers taken care of on automobiles.

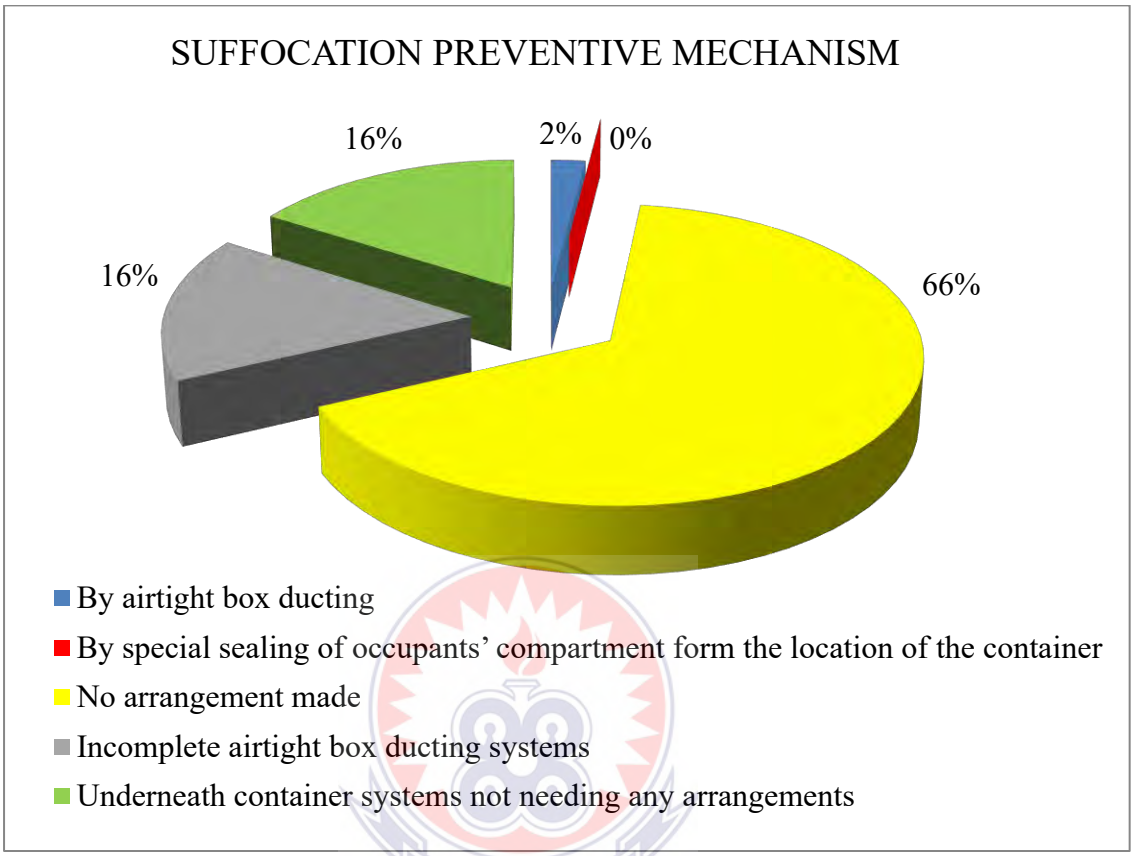


Figure 4.3. How suffocation of occupants by fumes from inside vehicle mounted containers taken care of.

Source: Field Survey (July, 2013)

Presented in Figure 4.4, is the pattern of how fillers of vehicles were mounted as discovered by the research.

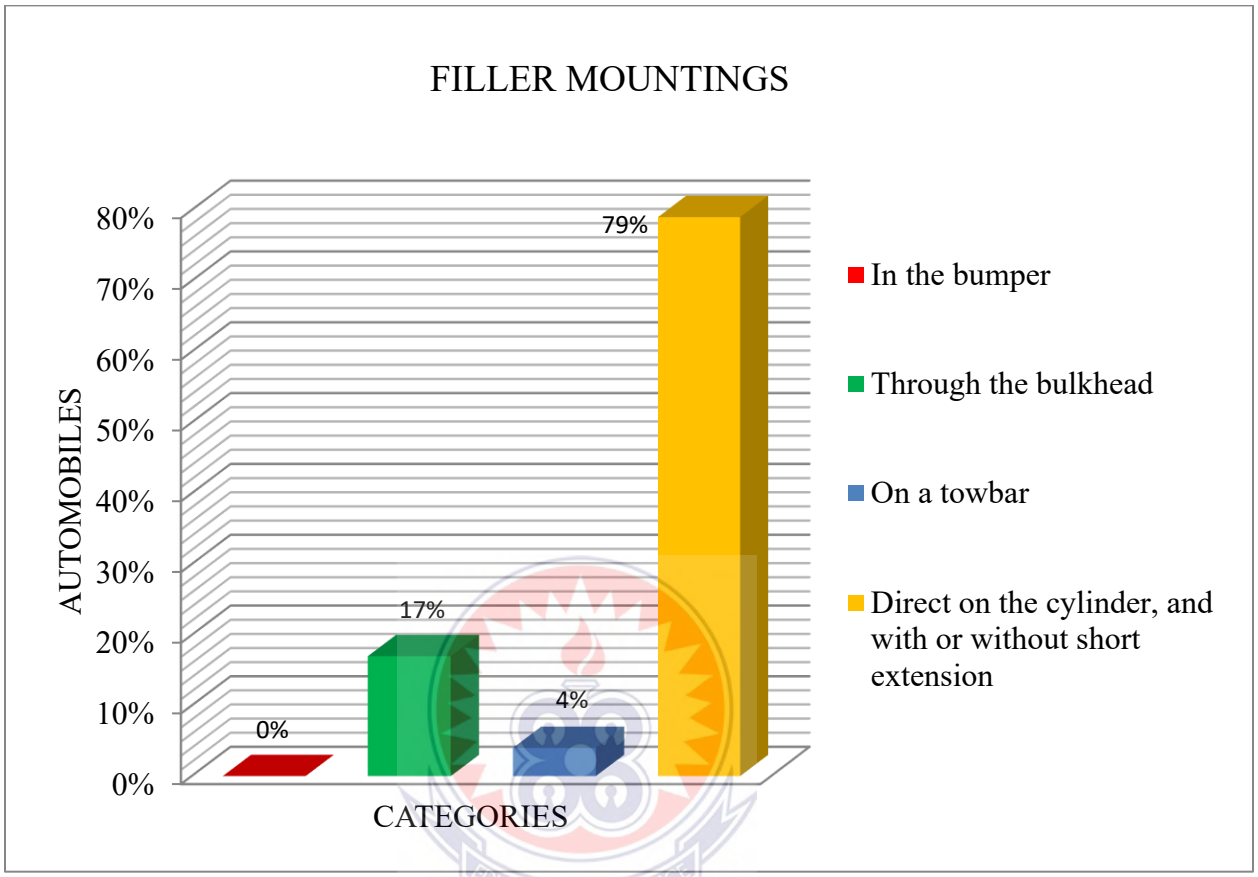


Figure 4.4. Pattern of how fillers of vehicles were mounted.

Source: Field Survey (July, 2013)

In the developments of Table 4.3, compliance of requirements on the fuel lines of vehicles were assessed and scored accordingly.

Table 4.3. Compliance of requirements on the fuel lines of vehicles

REQUIREMENTS OF FUEL LINES	AGREE		DISAGREE	
	Number	Percentage	Number	Percentage
1. All fuel lines connecting components in the fuel system should be a single continues piece of pipe.	160	75	52	25
2. No fuel line should be permitted to run through the inside of the vehicle, but along the underside.	92	43	120	57
3. Scratched pipes should not be used since they are termed stress raisers to breakages or failures.	147	69	65	31
4. All fuel lines, at least, should be separated 250mm away from vehicle exhaust system, and be secured at 600mm regular intervals.	212	100	0	0
5. The fuel line should be immediately coiled against vibration before connecting to the LPG solenoid valve, and between the LPG solenoid valve and the vaporizer.	20	9	192	91
6. Electrical device or apparatus such as electric windscreen wiper motors, electrically operated radio aerials, electric fuel pumps or stereo systems must not be fitted in the same vicinity occupied by the fuel container.	177	83	35	17

Source: Field Survey (July, 2013)

As to how the LPG Solenoid Valve is mounted to be protected in the event of an impact. Almost all LPG Solenoid Valves, with the exception of few, were mounted in the vicinity of the rear engine bulkhead in a protected area. Thus, 96 percent LPG Solenoid Valves were mounted in the vicinity of the rear engine bulkhead representing 204 vehicles. The rest 4 percent representing 8 vehicles of the sample size had their LPG Solenoid Valves mounted either on the right or the left side engine bulkhead.

Probing how vehicles were protected against backfiring, 45 percent representing 95 converted vehicles made use of some form of backfire arresters, whilst 117 vehicles representing 55 percent used the normal incorporated arrangements as an integral part of the designs, thus, ignition timing, mixer location and valve timing conditions to prevent the tendency of backfiring.

Table 4.4 represents the appropriate ratings of recommendations as applied to Electrical Wirings of converted LPG automobiles in the Ho Municipality.

Table 4.4. Ratings of recommendations as applied to Electrical Wirings of converted LPG automobiles in the Ho Municipality.

RECOMMENDATIONS OF ELECTRICAL WIRING	POOR		GOOD		VERY GOOD	
	Number	Percentage	Number	Percentage	Number	Percentage
1. Electrical connections done in accordance with authorized wiring diagram.	55	26	115	54	42	20
2. Wiring installations harnessed as much as practicable in a tidy fashion.	78	37	77	36	57	27
3. Avoidance of unapproved quick fit connections.	80	38	71	33	61	29
4. All joints soldered and insulated with heat shrink insulation.	51	24	93	44	68	32
5. Keeping all cables as short as practicable.	22	10	103	49	87	41
6. Fusing of current supplying cables (or the use of fusible links).	85	40	67	32	60	28
7. Mounting of all joints, electrical connections and units at vantage points to prevent water or liquid related interferences.	35	17	99	47	78	37

Source: Field Survey (July, 2013)

CHAPTER FIVE

FINDINGS AND DISCUSSIONS

This chapter which can simply be termed 'Discussion', identifies, interprets and discusses the significant and novel findings of the research in relation with the Literature Review. The highlights of the major findings are centered on the availability of required components of LPG converted automobiles, nature and conditions of safety features or devices, LPG fuel container situation and level of fullness, suffocation prevention and filler mountings, Compliance on fuel line requirements, and ratings of electrical wirings to recommendations. Photographs are however utilized to enhance the discussion.

5.1. AVAILABILITY OF REQUIRED COMPONENTS OF LPG CONVERTED AUTOMOBILES

No automobile can do without components like Electronic Vaporizer, Mixer, Fuel Container and Filler. All audited automobiles were found using these components in their various forms. LPG Solenoid Valve is also a necessity for all LPG automobiles, but was found lacking by 4 percent automobiles. The availability of all other required components as listed in Table 4.1 depend on the system design of a particular model of automobile as spelt out in the Literature Review.

Converted liquefied petroleum gas fuel supply system of an automobile discovered on the field of the study, comprising Electronic Vaporizer, LPG Solenoid Valve and Mixer incorporated Carburettor were as organized in the bonnet of the automobile shown in Figure 5.1. The location of the Mixer as clearly indicated in Figure 5.2, is at the point where the service line of the fuel supply system connects the Carburettor.

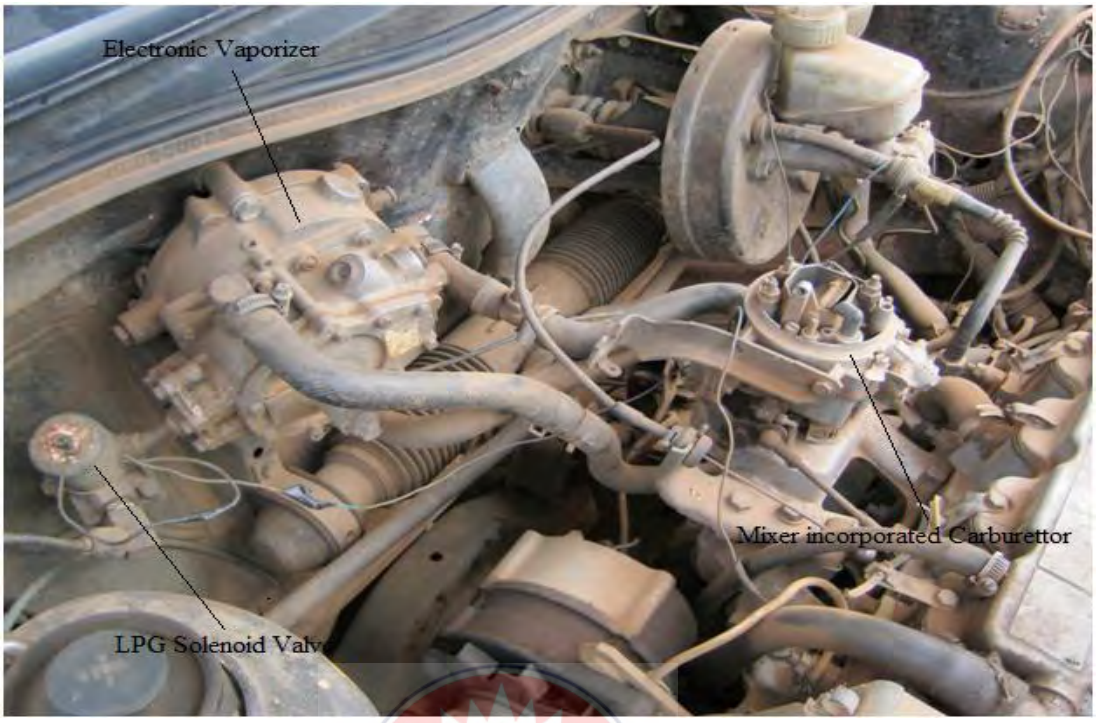


Figure 5.1. LPG Fuel system; comprising Electronic Vaporizer, LPG Solenoid Valve and Mixer incorporated Carburettor.

Source: Field Survey (July, 2013)

Figure 5.2. Mixer incorporated Carburettor, showing the location of the Mixer.

Source: Field Survey (July, 2013)

Mixer incorporated Electronic Carburettor in the LPG fuel supply system as shown in Figure 5.3 was using LPG and Petrol alternatively as fuel.

Figure 5.3. LPG Fuel system; making use of Mixer incorporated Electronic Carburettor. Using LPG and Petrol alternatively.

Source: Field Survey (July, 2013)

Displayed in Figure 5.4 is the Fuel injection system of an automobile using LPG and Petrol as fuel alternatively.

Figure 5.4. Fuel injection system; Using LPG and Petrol alternatively.

Source: Field Survey (July, 2013)

5.2. NATURE AND CONDITIONS OF SAFETY FEATURES OR DEVICES

The Fuel containers are said to be pressure vessels and potential sources of danger. In that wise all fuel containers should at least meet the satisfactory standard of requirements. In this research, majority of the containers (57%) were found satisfactory, 14 and 12 percents were good and very good respectively. About 17 percent containers were in deplorable state and were nothing to ride home about. An appalling situation captured in Figure 5.5 is hazardous and unauthorized domestic cylinder usage as fuel container in automobile with no secure embracement features. This development is a recipe for disaster which must never be encouraged. Domestic cylinders are not designed to withstand the pressures posed by automobile activities and can therefore

explode at the slightest provocation with its devastating consequences. It is however not recommended to use domestic cylinders as LPG fuel containers on automobiles. Ironically, the situation was found being practiced at the field.

Figure 5.5. Unauthorized domestic cylinder usage as fuel container in automobile.

Source: Field Survey (July, 2013)

Featured in Figure 5.6 is another hazardous and unsafe longitudinal mounting of cylindrical fuel container in the boot of automobile. A situation which would not allow the container to crumple on impact to prevent the transfer of forces but may result in severe injury to rear seat occupants. Secondly, the mounting straps of longitudinal mounted cylindrical fuel container are usually not strong enough to secure the container in that position without fail.

Figure 5.6. Unsafe longitudinal mounting of fuel container in the boot of automobile.

Source: Field Survey (July, 2013)

Correctly mounted direct fill cylindrical Fuel Container is located in the boot of automobile as in Figure 5.7, the recommended transversal mounting.

Figure 5.7. Transversal mounted Fuel Container, located in the boot of the automobile.

Source: Field Survey (July, 2013)

Fuel content gauges give information about the quantity of fuel in the vehicle at any given moment to enable the driver to ensure unfailing supply, the avoidance of fuel shortage at any given time. Without it, it is difficult to predict the safe arrival to destinations without any shortages of fuel. About 44 percent vehicles were not able to record the contents of fuel in their containers. Nine (9) percent of these vehicles were not having the content gauge and the rest 35 percent were either in poor or very poor states. Even though 56 percent of fuel content gauges ranged from satisfactory to very good, it does not form any good bases of reliability in transportation in the Municipality as a whole.

Overfilling prevention devices work with the correct angular mounting of fuel containers. Undue pressure built up in fuel containers due to overfilling affects fuel supply, leading to system

failure and tank explosions, which can be prevented by the use of float designed mechanism in the container that works automatically when the container is correctly mounted to the required angle. Indications have it that about 25 percent automobiles could not meet this standard of making judicious use of the mechanism. One can invariably guess the likely consequences of any vehicle which could not meet this safety standard.

Pressure relief valve works against the periodic built up of pressures in the container due to the surge and temperature conditions of the content of the container. All vehicles were having this device with the exception of only 8 percent that were in poor state. Forty two (42) percent were however in very good state.

Automatic fuel shut-off device is an emergency safety mechanism that automatically prevents the supply of fuel to the service line and the vaporizer, when the ignition switch and for that matter the engine is not working. Unless there is an actual need for fuel supply demanded by the driver though the ignition switch, fuel will not be permitted to continuously flow into the supply line. As such, any form of incident or accident that succeeds in disconnecting the fusible link of the ignition system prevents fuel flow to safeguard the entire vehicle system from fire related consequences. Automobiles that were not having this feature stood at 10 percent, 5 percent were poor and 1percent very poor.

Manual shut-off valve, unlike the automatic fuel shut-off device, is operated manually to shut down fuel supply from the container in the events of accident, maintenance and when parking the automobile for periods of time without being used. A number of vehicles were not having this

facility with the reason that by the use of the automatic fuel shut-off device, the manual shut-off valve might not be necessary.

Non return valves were found on all vehicles with majority in remarkable states. These features ensure one directional flow of fuel when the tank is being filled, and when fuel is being supplied in to the service line to avoid the hazards of reverse flow possibilities. Five (5) percent non return valves were found leaking which may be due to lack of maintenance.

Vents for escape of gases were also found on all vehicles. They were designed at vantage points of the fuel system to expel unduly stacked pressure built ups that could cause changes in the fuel supply pattern and leakages in the fuel system in general.

Airtight box and its ducting system or approved sealing that prevents suffocate of occupants on board had not been the best. Fifty nine (59) percent automobiles were not having any of these arrangements. In total, 87 percent automobiles could not meet these requirements; implying occupants were being suffocated in these vehicles. Figure 5.8 shows such incomplete airtight box system on Toroidal Fuel Container of automobile located in the spare wheel well.

Figure 5.8. Toroidal Fuel Container; located in the spare wheel well with incomplete airtight box system.

Source: Field Survey (July, 2013)

Excess flow valve availability stood at 55 percent with only 20 percent in very good state. According to the literature review, "It is set to be in the open state and automatically closes when the flow in a given direction exceeds predetermined limit under abnormal conditions as pipe ruptures, in order to avoid leakage".

Catalytic converter usage on LPG converted automobile promotes cleaner exhaust into the atmosphere. Accurate feedback system of the catalytic converter, made possible by the use of lambda sensor, improves vehicle performance and fuel economy, and the use of lambda probe constantly recalibrate the system for maximum power and efficiency. Unfortunately, 21 percent automobiles were not having catalytic converters and 5 percent lambda sensors of the catalytic

converters were found not functioning. In effect, these automobiles are bound to pollute the atmosphere against International Safety Standard.

Electrical relay and Backfire arrester are to be used by some particular type of automobiles. As such, majority of automobiles researched into were not having these particular features. However, 15 and 10 percents Electrical relay and Backfire arrester respectively were found at various evaluated states.

5.3. LPG FUEL CONTAINER SITUATION AND LEVEL OF FULLNESS

Fortunately, no LPG fuel container was located in the engine compartment for safety reasons. In fact, 50 percent was situated inside the boot, 34 percent in the spare wheel well and 16 percent underneath the floor of the boot. These are the best locations that met the International Safety Standards.

With regard to fullness, 80% capacity of fullness formed the majority and 90% to 95% capacity of fullness in the minority. It is surprising to have noticed that as much as 12 percent registered 100% capacity of fullness. This situation suggests non performance of devices responsible to check the level of fullness. It is however not safe to have the container completely full. The International Safety Standards recommended a number of levels of fullness but not at all 100% capacity of fullness.

5.4. SUFFOCATION PREVENTION AND FILLER MOUNTINGS

Arrangements against suffocation of occupants had nothing to ride home about. Virtually all automobiles evaluated had no form of complete system to cater for occupants on this menace. Revealed in Figure 5.9 is unsealed passenger compartment from LPG fuel container, and no containment ducting with the aid of airtight box. Similarly, Figure 5.8 above had incomplete airtight box system arranged on toroidal fuel container in spare wheel well of the boot which is also of no good commendation.

Figure 5.9. Unsealed passenger compartment from LPG fuel container, and no Containment ducting with the aid of airtight box.

Source: Field Survey (July, 2013)

Filler Mountings of LPG converted automobiles had not been much. Seventy nine (79) percent vehicles had their filler mountings direct on the cylinders, and with or without short extensions. There was no bumper mountings, and through the bulkhead mountings stood at 17 percent

automobiles. The most ideal filler locations for converted LPG and petrol alternative fuel automobile are shown in Figure 5.10.

Figure 5.10. Ideal Filler locations for converted LPG and petrol alternative automobile.

Source: Field Survey (July, 2013)

As to how the liquefied petroleum gas and petrol work alternatively, Figure 5.11 indicating the LPG and Petrol alternative switch unit located on the instrument panel of the driver's compartment is used to switch the two types of fuel. This type of switch happened to be one of the best on the research. It is incorporated with electronic fuel level indicator that illuminates depending on the quantity of content of fuel.

Figure 5.11. LPG and Petrol alternative Switch Unit location.

Source: Field Survey (July, 2013)

5.5. COMPLIANCE ON FUEL LINE REQUIREMENTS

The requirement of all fuel lines connecting components in the fuel system should be a single continues piece of pipe had not been completely met. Twenty five (25) percent automobiles were found having their fuel lines as split joints. A recipe for leakage development that is tantamount to failures, since these joints serve as stress raisers.

Fifty seven (57) percent automobiles had also failed to meet the requirement that no fuel line should be permitted to run through the inside of a vehicle, but along the underside. As can be discovered in Figure 5.12 is unrecommended Fuel Supply Line passed through inside vehicle at the passenger side of the automobile and covered with interior liner. A number of practitioners

Figure 5.12. Fuel Line passed through inside vehicle at the passenger side of the automobile.

Source: Field Survey (July, 2013)

argued that by passing the pipe through the inside under the cover of the interior liner at the passenger side, they consider it equally safe since no external objects can get entangled with it to cause any form of rupture that could lead to any havoc. It must be noted that any pipe that is properly laid cannot experience any form of rupture. There were no problems with the proximities of the fuel lines and the exhaust system, but scratched pipes were found in use as much as 31 percent. As part of requirements, scratched pipes should not be used since they are also termed stress raisers to breakages or failures.

Only 9 percent converted automobiles met the requirement that stipulated that fuel lines should be immediately coiled against vibration before connecting to the LPG solenoid valve, and between the LPG solenoid valve and the vaporizer. Instead of coils, rubber hoses having the

same anti vibration qualities were utilized, provided they were as strong to withstand the pressures of the system.

5.6. RATINGS OF ELECTRICAL WIRINGS TO RECOMMENDATIONS

The recommendation of electrical connections being done in accordance with authorized wiring diagram fell short of by 26 percent automobiles, whilst 20 percent were in very good state. Wiring installations which should also be harnessed as much as practicable in a tidy fashion was rated and found fall short of by 37 percent automobiles. Disastrous untidy fashion of electrical wiring in converted LPG dedicated automobile is pictured in Figure 5.13.

Figure 5.13. Untidy fashion of electrical wiring in converted LPG dedicated vehicle.

Source: Field Survey (July, 2013)

Thirty eight (38) percent automobiles fell short of the avoidance of unapproved quick fit connections which were common places in some vehicles. Fusing of current supplying cables or

the provision of fusible links to safeguard circuits of the automobile had also not met the required standards by 40 percent automobiles.

On the average, the rating of electrical wirings of automobiles to the required recommendations registered 73 percent perfection, but this is an area where higher scores must be expected due to the havoc non compliance of the International Safety Standards can pose to the entire automobile using liquefied petroleum gas as fuel. Meanwhile, further details of photography at the field of the study are shown in appendices A, B, C and D.

CHAPTER SIX

SUMMARY OF FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

This concluding chapter deals with the salient points of the major research findings, the fate of the situation, with suggestions and recommendations. Its subsections are the Summary of Findings, Conclusions, Recommendations or Suggestions, and Suggestions for Further Research.

6.1. SUMMARY OF FINDINGS

The availability of the required components of LPG converted automobiles depends on the system design of a particular model and make. However, all audited automobiles were found using their required components in various acceptable states with the exception of Solenoid Valve which some considerable number of automobiles was lacking.

With regards to the nature and conditions of safety features and devices, most automobiles had commendable features or devices that met International Safety Standards. Considerable number of automobiles had their features in deplorable and unacceptable states. Coupled with unavailability of some expected features that contribute to greater safety, was certain practices including the use of domestic cylinders as fuel container and longitudinal mountings of cylindrical containers in the boot that must never be allowed in the sector of transportation with LPG converted automobiles.

For effective operation that ensures safety, no LPG fuel container was located in the engine compartment. They were all situated in locations that met International Safety Standards. Meanwhile, the levels of fullness of some of these containers leave much to be desired.

Virtually all automobiles evaluated had no forms of suffocation prevention arrangements to protect the health of occupants against fumes of fuel. Also, filler mountings were mostly limited to on the cylinder or container directly with or without short extensions.

Compliance on fuel line requirements, though in the majority, had not been adequate. Split joints and scratched pipes which are stress raisers to leakages and failures were all in practice to some disastrous extent. The passage of fuel lines through inside vehicle which should have been avoided was common place, although there were no problems with proximities of fuel lines and exhaust system. Rubber hoses were also utilized instead of coiled pipes against vibration and internal pressures.

Even though ratings of electrical wirings to recommendations registered high scores, much is left to be desired. Connections being done in accordance with authorized wiring diagrams fell short of considerably and tidy fashions of wire harness on some automobiles were recipes for havocs. Avoidance of unapproved quick fit connections and the use of fuses or fusible links to safeguard circuits had been seriously abused by some automobiles.

6.2. CONCLUSIONS

The Volta Regional Capital, Ho, is geographically small but recognized nationwide as a fast developing city. Its vehicular and human population growths would not do any good if concerted efforts are not made to ensure the caliber of automobiles plying its roads comply with International Safety Standards as far as liquefied petroleum gas usage is concerned.

It is evident, and cannot be over emphasized, that protection of lives and properties should be given topmost priority in every human endeavour. Compliance with standardized nature and conditions of automobiles is the only sure and the most basic ways of eradicating or mitigating havocs or vehicular related accidents on our roads and giving way to accelerated economic, social and national developments to the benefits of all.

In view of these potentials, it is imperative that converted liquefied petroleum gas automobiles in the Ho Municipality are updated to meet Modern Developmental and International Safety Standard requirements, regardless of how much cost might be incurred in achieving its noble aim. And since vehicular accidents are no respecter of person, cost must not be compromised with safety.

6.3. RECOMMENDATIONS / SUGGESTIONS

The following recommendations are made to meeting Modern Developmental and International Safety Standards of converted liquefied petroleum gas automobiles in the Ho Municipality:

(I) Driver and Vehicle Licensing Authority (DVLA) should liaise with Industrial Associations to be well equipped with the technological knowhow on the concept of converted LPG automobiles

so as to be able to identify and insist on the required components of any given system design of a particular model and make of automobile and their compliance with standards before the declaration of such vehicles as road wealthy to ply the streets of the Ho Municipality.

(II) The Motor Traffic Unit (MTU) of the Ghana Police Service should be equally given in-depth knowledge on what to check on converted LPG automobiles in order to curb certain practices that are recipes for havocs.

(III) Government must make it a decree for all converted LPG automobiles to have suffocation prevention arrangements to protect the health of occupants against fumes of fuel with appropriate filler mountings.

(IV) Emphasis must be laid on compliance of fuel line requirements, since it is one of the most disastrous aspects to tamper with on the automobile.

(V) Measures must be put in place to ensuring that practices of recommendations on electrical wirings also meet the requirements of the International Safety Standards, since it is a potential source of spark of fire.

(VI) There must be continual and aggressive inspection on all converted LPG automobiles to ensure compliance with the International Safety Standards, regardless of what might be incurred to ensuring the uttermost safety of lives and properties.

(VII) All LPG automobile drivers must be educated by DVLA on handling LPG automobiles for sanity and greater safety.

(VIII) All individuals and organizations that are in the conversion practice should be thoroughly educated, examined and certified to ensuring the doing of right practices that meet International Safety Standards.

(IX) All law enforcing organizations must update their technological knowhow to intensify vigilance on converted LPG automobiles and their practitioners including drivers to make transportation more reliable.

It is believed, by the implementation of these congenial proposals, automobile related accidents and for that matter carnage on our roads and other havocs regarding converted liquefied petroleum gas automobiles can be mitigated or reduced drastically to the barest minimum if not totally eradicated.

6.4. SUGGESTIONS FOR FURTHER RESEARCH

In the larger interest of the nation as a whole, this exercise is suggested to be carried out in all the ten capital cities of the country and be extended to other metropolitans, municipals and districts as a measure of improving safety on liquefied petroleum gas converted automobiles usage for national development, which of course should be supported with the appropriate funding for enhancement.

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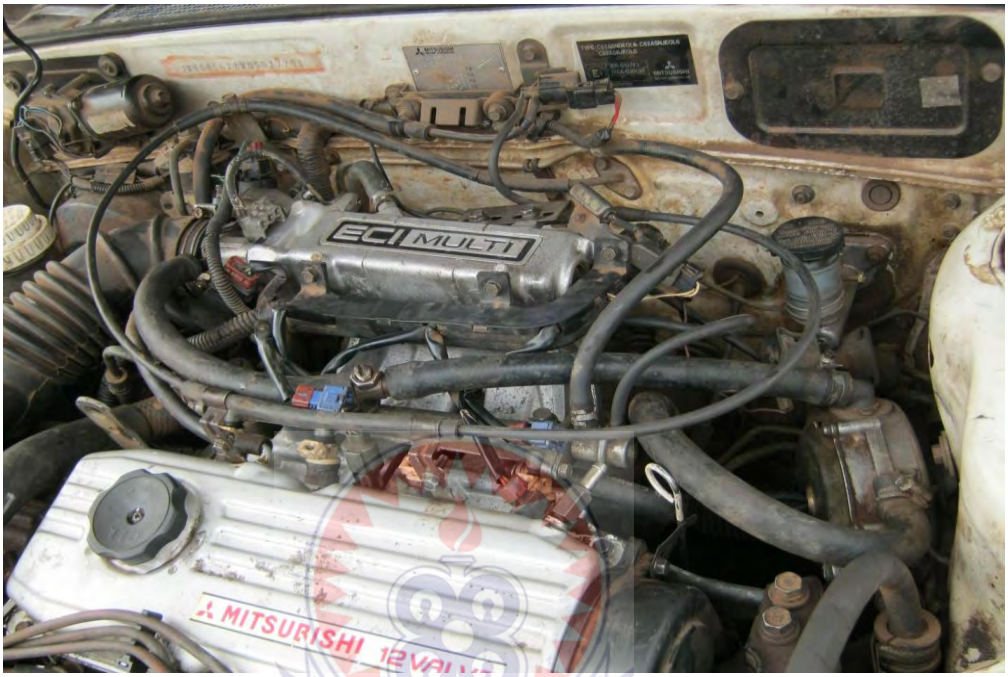
APPENDICES

Appendix A. Two deferent types of converted Fuel injection systems; Using LPG and Petrol alternatively.



Source: Field Survey (July, 2013)

Appendix B. Two deferent types of converted LPG Mixer incorporated Electronic Carburettor systems. Using LPG and Petrol alternatively.

Source: Field Survey (July, 2013)

Appendix C. Five deferent types of liquefied petroleum gas fuel container designs put together.

Source: Field Survey (July, 2013)

Appendix D. Light commercial converted automobile; Using LPG and Petrol alternatively.

Source: Field Survey (July, 2013)

Appendix E. Research Instruments of the study.

UNIVERSITY OF EDUCATION, WINNEBA

COLLEGE OF TECHNOLOGY EDUCATION, KUMASI

MASTER OF MECHANICAL TECHNOLOGY EDUCATION

RESEARCH INSTRUMENTS

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VEHICLE'S BASIC INFORMATION

Make of vehicle:……. Model:…….

Date of conversion:…….. Date of audit:……

Fuel system: ☐ Carburetor or ☐ Fuel injection

System design: ☐ LPG Dedicated or ☐ Dual fuel (Petrol and LPG)

OBSERVATION GUIDE OR SCHEDULE

1. Check the availability of Components of the LPG converted automobile in the table below:

COMPONENTS OF LPG AUTOMOBILE	Available	Not available	Remark
1. Electronic Vaporizer or Reducer			
2. LPG Solenoid Valve			
3. Switch Unit			
4. Mixer			
5. Fuel Container			
6. Multivalve			
7. Filler			
8. Petrol Solenoid Valve			
9. Injection Emulator			
10. Airtight Box			
11. Backfire Arrester			

General Comments:……..

2. Examine and score the nature and conditions of safety features or devices listed in the table below as a prime factor to ensuring safety in the LPG conversion practice:

SAFETY FEATURES, DEVICES AND THEIR RANKING	Not available (0)	Very Poor (1)	Poor (2)	Satisfac tory (3)	Good (4)	Very good (5)	Remark
1. Fuel container or tank							
2. Fuel content gauge							
3. Overfilling prevention device							
4. Pressure relief valve							
5. Automatic fuel shut-off device							
6. Manual shut-off valve							
7. Non return valves							
8. Vents for escape of gases							
9. Airtight box or approved sealing							
10. Excess flow valve							
11. Catalytic converter							
12. Electrical relay							
13. Backfire arrester							

General Comments:……

*Note: Use camera where necessary.

INTERVIEW SCHEDULE

3. Is your catalytic converter operational after the conversion? ☐ Yes ☐ No

4. If No, which of the following are disconnected?

a) ☐ Catalytic converter
b) ☐ Emission and engine control systems
c) ☐ Emission control systems
d) ☐ Fuel emission systems
e) ☐ Engine control and management systems
f) ☐ Oxygen sensors
g) ☐ Non of the above

5. How is the LPG fuel container of your vehicle situated?

a) ☐ In the engine compartment
b) ☐ Inside the boot

c) ☐ Underneath the floor of the boot
d) ☐ In the spare wheel well
e) ☐ Contained within the chassis of the vehicle
f) ☐ Others (specify)……

6. At what level of fullness does the safety shut off of fuel of your vehicle come to operation when filling the tank?

a) ☐ 80% capacity of fullness
b) ☐ 80% to 85% capacity of fullness
c) ☐ 85% capacity of fullness
d) ☐ 90% to 95% capacity of fullness
e) ☐ 100% capacity of fullness

7. How is suffocation of occupants by fumes from inside vehicle mounted container taken care of on your vehicle?

a) ☐ By airtight box ducting
b) ☐ By special sealing of occupants' compartment form the location of the container
c) ☐ No arrangement is made
d) ☐ Others (specify)……

8. How is the filler of your vehicle mounted?

a) ☐ In the bumper
b) ☐ Through the bulkhead
c) ☐ On a towbar
d) ☐ Others (specify)……

9. Check the compliance of the following requirements on fuel lines of your vehicle:

a) All fuel lines connecting components in the fuel system should be a single continues piece of pipe. ☐ Agree ☐ Disagree
b) No fuel line should be permitted to run through the inside of the vehicle, but along the underside. ☐ Agree ☐ Disagree
c) Scratched pipes should not be used since they are termed stress raisers to breakages or failures. ☐ Agree ☐ Disagree

d) All fuel lines, at least, should be separated 250mm away from vehicle exhaust system, and be secured at 600mm regular intervals. ☐ Agree ☐ Disagree

e) The fuel line should be immediately coiled against vibration before connecting to the LPG solenoid valve, and between the LPG solenoid valve and the vaporizer.
☐ Agree ☐ Disagree

f) Electrical device or apparatus such as electric windscreen wiper motors, electrically operated radio aerials, electric fuel pumps or stereo systems must not be fitted in the same vicinity occupied by the fuel container. ☐ Agree ☐ Disagree

10. How is your LPG Solenoid Valve mounted to be protected in the event of an impact?
.....
.....

11. How is your vehicle protected against backfiring? .....
.....
.....

12. Rate as appropriate the following recommendations as applied to Electrical Wiring of a converted LPG automobile:

RECOMMENDATIONS OF ELECTRICAL WIRING	POOR	GOOD	VERY GOOD	REMARK
1. Electrical connections done in accordance with authorized wiring diagram.				
2. Wiring installations harnessed as much as practicable in a tidy fashion.				
3. Avoidance of unapproved quick fit connections.				
4. All joints soldered and insulated with heat shrink insulation.				
5. Keeping all cables as short as practicable.				
6. Fusing of current supplying cables (or the use of fusible links).				
7. Mounting of all joints, electrical connections and units at vantage points to prevent water or liquid related interferences.				

General Comments:.....